

Assessing Ecological Risk of Proposed Mines: Can Valid Assessments be Done Pre-Design?

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Executive Summary

Background

Large resource development projects take years to plan. During that planning time, the public frequently debates the potential benefits and risks of a project, but with incomplete information. In these debates, some people might assert that a project would have great benefits, while others might assert that it would certainly harm the environment. At the same time, the developer will be assessing different designs, before finally submitting one to the government permitting agencies for evaluation and public scrutiny.

For large mines in Alaska, the government permitting process takes years, and often includes an ecological risk assessment. This assessment is a data-intensive, scientific evaluation of the project's potential ecological risks, based on the specific details of the project.

Recently, some organizations have tried to bring scientific rigor to the pre-design public discussions, especially for mining projects, through a *pre-design* risk ecological risk assessment. This is a scientific assessment of the environmental risks a project might pose, before the details of project design, risk-prevention, and risk-mitigation measures are known.

It is important to know whether pre-design risk assessment is a viable method for drawing conclusions about risks of projects. If valid risk predictions can be made at that stage, then people or governments would not have to wait for either a design or for the detailed evaluation that is done during the permitting process. Such an approach could be used to short cut permitting. It could affect project financing; it could affect the schedule, priority, or even the resources that governments put toward evaluating a project. But perhaps most important: in an age where public perceptions are an important influence on a project's viability and government permitting decisions, a realistic risk assessment can be used to focus public attention on the facts. But if the methodology is flawed and results in poor quality information and unsupportable conclusions, then a pre-design risk assessment could unjustifiably either inflame or calm the public, depending on what it predicts.

Scope of the Paper

This paper analyzes the validity of pre-design ecological risk assessments for mining projects. It does so by defining some concepts about risk, summarizing the EPA's guidelines for an ecological risk assessment, and discussing three ecological risk assessments for mining projects in Alaska: post-design risk assessments for the Kensington and Red Dog mines, and a pre-design assessment for the proposed Pebble mine.

A Note about the Pebble Mine Project

The Pebble mine project is an advanced mineral exploration project within the Bristol Bay watershed in southwest Alaska. Bristol Bay is also home to the world's largest red salmon run and significant commercial, subsistence, and sport fisheries. The project is still in the planning stage, but has already caused a huge amount of public discussion, advertising, lawsuits, and assertions.

Given that controversy, and because this paper analyzes a pre-design risk assessment for the Pebble project, it is worthwhile to emphasize what the paper is not. This paper is not a defense of the Pebble project, and it is not a critique of that project. It evaluates the applicability and scientific value for mine projects of a pre-design ecological risk assessment. It does not examine or draw conclusions about whether the Pebble mine itself would be high or low risk. It only evaluates whether a pre-design ecological risk assessment can adequately predict project risks, whatever they might be.

Analysis and Discussion

Overview of Ecological Risk

The paper begins with an overview of ecological risk. It describes how risk to the environment is a big part of public discussions about proposed projects.

EPA defines risk in this context as the “chance of harmful effects to . . . ecological systems.” This paper defines prevention as an activity to prevent a harmful event from occurring, and mitigation as an activity to limit the severity of a problem once it occurs. An ecological risk assessment must take into account prevention and mitigation activities, or it is likely to misrepresent actual ecological risks.

Ecological Risk Assessment Process

Ecological risk assessments are done under a set of guidelines developed by the EPA and published in the Federal Register in 1998. The process is typically data-intensive, using specific information about a project and the surrounding environment to determine the risk to specific resources. This paper briefly summarizes that process, as well as describing the distinction between ecological and engineering risk and the role of the public in risk assessments.

Examples of Post-Design Ecological Risk Assessments

Ecological risk assessments are frequently completed during the Environmental Impact Statement (EIS) process for mines in Alaska, when government permitting agencies are evaluating a project. During the permitting process, the project design is known, along with prevention and mitigation activities that the developer proposes or the government will impose on the project. To illustrate the process and level of detail involved in this process, this paper examines two post-design ecological risk assessments.

The first example is an ecological risk assessment that was done of proposed tailings disposal for the planned Kensington gold mine. The assessment evaluated the risk of harm to fish and wildlife from the developer’s proposal to put gold mine tailings in a lake near the mine. This assessment was prepared during the mine’s permitting evaluation and published as part of the project’s supplemental Environmental Impact Statement.

The second example is an ecological risk evaluation that targeted fugitive dust along the Red Dog mine road. This evaluation was done after evidence showed that dust from trucks hauling Red Dog ore was causing metals to accumulate along the road. The study assessed the risk that the metals were contaminating streams, fish, and subsistence foods.

The discussion in the paper shows that both assessments used detailed site-specific information, testing, and environmental data to come to their conclusions. For example, the Kensington study included detailed tests of Kensington tailings on water quality and vegetation growth, as well as tests that documented the bioaccumulation of metals in benthic organisms taken from Kensington-specific tailings. The Red Dog assessment collected metal concentrations in soil, water, and vegetation from a variety of environments. The assessments projected potential contaminants, after the prevention and mitigation strategies had been applied.

Information, environmental characteristics, and prevention and mitigation strategies change from mine to mine. The post-design environmental risk assessments described in this paper used project-specific data to come to conclusions about the risks of particular situations. This detailed project information, a multitude of other project-specific tests, and environmental data from the specific areas were necessary for the ecological risk assessments to come to credible conclusions.

Example of a Pre-Design Ecological Risk Assessment

In October 2010, The Nature Conservancy published *An Assessment of Ecological Risk to Wild Salmon Systems from Large-scale Mining in the Nushagak and Kvichak Watersheds of the Bristol Bay Basin*. It is the first formal pre-design ecological risk assessment published for a project in Alaska. It attempts to scientifically assess the ecological risks of the Pebble mine project to Bristol Bay salmon—an indisputably important resource. It concludes that this assessment of risks is relevant to mines “regardless of their design” and that they would apply “to any large mine development in the [Bristol Bay] region.”

This paper analyzes five subjects included in The Nature Conservancy’s assessment:

- Acid rock drainage
- Water withdrawal
- Culvert impacts
- Fugitive dust
- Dam failure

For each of these subjects, this analysis demonstrates that the Nature Conservancy’s analysts lacked the data needed to evaluate the specific environmental characteristics of the mine (dust, water use, water quality, and others), and so were forced to make unjustified and unrealistic assumptions about what would happen if the mine were developed. In addition, because the mining companies have not yet submitted a project design, the conservancy’s assessment omits prevention and mitigation strategies that could be used to reduce risk.

This paper does not conclude that the Pebble Project or any other large mine in Bristol Bay will be high risk or low risk. It simply concludes that the pre-design assessment published by the Nature Conservancy lacked the data to support its analysis. As a result, the pre-design ecological risk assessment came to scientifically unsupportable conclusions about the risks to salmon of a Pebble mine or any other large mine project in Bristol Bay.

Conclusions

Scientifically sound ecological risk assessments require a great deal of data. The *post*-design assessments analyzed in this paper used detailed data that were the result of testing done for the specific parameters of the Kensington mine and the Red Dog mine road. The paper makes clear that the specific environmental characteristics of the sites and the project-specific details were a necessary basis for the conclusions these studies draw.

Every hard-rock mine is unique. The methods used to protect water quality and fish populations are different from mine to mine. The milling processes are engineered for individual mines and result in environmental outputs with different characteristics. These and other differences influence the ecological risk characteristics of individual mines.

The Nature Conservancy’s *pre*-design ecological risk assessment lacked project-specific design details and used limited information to project what would happen if the mine were developed. It introduced bias by making unrealistic assumptions about the as-yet unknown design and by omitting prevention and mitigation strategies. As a result, its conclusions are not reliable.

In summary:

- Post-design ecological risk assessments use detailed project-specific and site-specific data to come to credible conclusions.
- Hard-rock mines are unique, and data from one mine is unlikely to represent another.
- The pre-design ecological risk assessment reviewed in this paper used unreliable assumptions in the absence of actual design details, and failed to include the as-yet-unknown prevention and mitigation strategies. These omissions caused the pre-design risk assessment to come to unsupportable conclusions.

For these reasons, this paper concludes that a pre-design ecological risk assessment is a failed methodology for evaluating the risks posed by hard-rock mines in Alaska.

Section 1. Introduction

Background

Large resource development projects—such as mines, or oil and gas fields—take years to plan. During that time, the public debates these projects with incomplete information: Will it be economic? Will it harm the environment? Will the salmon be protected? What is the risk? Despite the public debate, the specific effects on the environment typically can't be resolved at this early stage, because the public and sometimes even the project developer are unsure of the eventual project design. The debate continues while the project owner continues to plan and refine the project.

In a typical situation, after the project developer comes up with a design, there is a government fact-finding investigation—an environmental impact statement or similar analysis—that arrives at answers to the environmental questions. That evaluation process also often includes an ecological risk assessment: a data-based, scientific evaluation of the potential risks to ecosystems from a proposed large resource development project. The government studies a real project design and gathers data to answer specific questions. Sometimes government agencies require more data before they are satisfied. While people may disagree with the conclusions of a government study, for the government permitting agencies, the study provides answers based on accepted scientific methodologies and a great deal of project-specific data.

But recently, some organizations have tried to bring scientific rigor to the public discussion before the developer has submitted a project design. In October 2010, The Nature Conservancy published an ecological risk assessment that outlined the risks to salmon of large-scale mining in the Bristol Bay watershed in southwest Alaska. The Environmental Protection Agency (EPA) appears to be completing a pre-design risk assessment of mining as part of its Scientific Assessment of the Bristol Bay Watershed, though the agency's methodology is unknown as of late 2011. Pre-design, scientific assertions about environmental risk have been made in debates about other projects as well.

A scientific *pre-design* risk assessment is an innovative approach. The 2010 ecological risk assessment by The Nature Conservancy is the first time in Alaska that a scientific assessment has been attempted before project details are available—before a mine plan, with associated risk prevention and risk-mitigation strategies, has been submitted.

It's important to know whether pre-design risk assessment is a viable method for drawing conclusions about risks of projects. If valid risk predictions can be made at that stage, then people or governments would not have to wait for either a design or the detailed evaluation that is done during the permitting process. Such an approach could be used to short cut permitting. It could affect project financing; it could affect the schedule, priority, or even the resources that governments put toward evaluating a project. But perhaps most important: in an age where public perceptions are an important influence on a project's viability and government permitting decisions, a realistic risk assessment can be used to focus public attention on the facts. But if the methodology is flawed and results in poor quality information and unsupportable conclusions, then a pre-design risk assessment could unjustifiably either inflame or calm the public, depending on what it predicts.

Purpose of This Paper

This paper analyzes the validity of pre-design ecological risk assessments for mining projects. It first defines some concepts about risk, explains why ecological risk plays such an important part in public debates about proposed projects, and summarizes the EPA's guidelines for an ecological risk assessment. It then describes how scientific assessments of risk are carried out, and discusses three ecological risk assessments for mining projects in Alaska: post-design risk assessments for the Kensington and Red Dog mines, and The Nature Conservancy's pre-design assessment for the proposed Pebble mine.

A Note about the Pebble Mine Project

The Pebble mine project is an advanced mineral exploration project within the Bristol Bay watershed in southwest Alaska. The mining company is expected to propose a large open-pit mine. Bristol Bay is also home to the world's largest red salmon run and supports significant commercial, subsistence, and sport fisheries. The mine project is still in the planning stage, but it has already caused a huge amount of public discussion, advertising, lawsuits, and assertions.

Given that controversy, and because this paper analyzes a pre-design risk assessment for the Pebble project, it is worthwhile to emphasize what this paper is *not*. It is not a defense of the Pebble project, and it is not a critique of that project. It evaluates the applicability and scientific value for mine projects of a pre-design ecological risk assessment. It does not examine or draw conclusions about whether the Pebble mine itself would be high or low risk. It only evaluates whether a pre-design ecological risk assessment can adequately predict project risks, whatever they might be.

Section 2. Overview of Ecological Risk

The Importance Of Risk In The Public Discussion

An important part of the public discussion about large resource projects is typically about the ecological risks a proposed project may create. The Pebble mine project provides an excellent example of the importance the public places on knowing about potential risks to ecosystems. Much of the widespread and contentious public discussion about the project revolves around people's perceptions of the risks it may pose to the environment of the Bristol Bay watershed.

Opponents of the potential Pebble mine have focused on the risk to salmon, with some asserting “there is a virtual certainty” that the mine would contaminate the salmon fisheries¹ and others saying that the mine “could” harm waters, communities, and fisheries—and that such a risk is not worth taking.²

Mine proponents, not surprisingly, assess the risk differently, citing “responsible mining technologies” that make it possible for the fisheries and the mine to co-exist.³ Staff of the mining project, in conversations with the author, have said they believe a mine can be designed with limited risk to salmon.⁴

Some observers are waiting for more information before drawing conclusions about the project. In observing the dispute for the last five years, the author has seen that different people look at the project and come to different conclusions about how risky it will be to salmon. Part of that difference may be due to differences in how much risk people are willing to accept. But part may also be due to a factual dispute about the size of the risk.

The controversy over the proposed Pebble mine is currently the highest-profile public debate about a proposed Alaska resource development project, but there are other examples of similar controversies about other large development projects. Certainly, some elements of the debate about the risks of the proposed Pebble mine have been part of public discussions about most large mine projects in Alaska.

Conceptual Discussion of Ecological Risk

To understand the process of ecological risk assessment, it is important to understand the basic concepts of “ecological risk.”

What is Risk?

There are many definitions of risk. For scientific assessments of ecological risk, EPA defines risk as “chance of harmful effects to . . . ecological systems.”⁵ A systematic, scientific process will try to define both the “chance” and the “harm.” It should describe the likelihood of harm, and precisely describe what harm is being evaluated.

What is the Role of Prevention and Mitigation?

Prevention and mitigation are useful concepts for the discussion of risk. Some activities that companies or governments use to address risk are aimed at preventing a problem, and some activities are intended to contain the severity of a problem after it has occurred. For example, drivers can help *prevent* a car crash (the problem) by maintaining their cars in good working

¹ Web page for Wild Salmon Protection, Inc.; www.wildsalmonprotection.com; 7/14/11.

² Brian Kraft, quoted in the newsletter for the Alaska Center for the Environment. Center News, Winter 2004.

³ Web page for The Pebble Partnership; <http://www.pebblepartnership.com/>; 7/14/11.

⁴ Numerous personal conversations with the author over the last five years.

⁵ EPA Risk Assessment website: <http://epa.gov/riskassessment/basicinformation.htm#arisk>; 10/21/11.

order, keeping the tires inflated, and driving the speed limit. But if a crash happens anyway, airbags and seatbelts can *mitigate* the severity of the crash.

In the real world of mine regulation, some activities have the characteristics of both prevention and mitigation—both helping prevent a problem and limiting its effects. For example, an intensive inspection regime may help keep an oil storage facility working properly to prevent leaks, and it may also detect leaks early, to limit their effects.

An Example: Prevention and Mitigation Strategies in a Risk Assessment

An example will illustrate how prevention and mitigation strategies affect an ecological risk assessment. A hypothetical Alaska village sits on the bank of a river; fuel and supplies are transported to the village via the river, but the river is also an important source of subsistence fish. The village decides it needs to store fuel to supply generators for electricity, because fuel can only be delivered during the few months when the river is ice-free.

Thirty years ago, the village might have installed a single-walled fuel tank right on the bank of the river. Single-walled fuel tanks have a high incidence of leaking. If there were a 1% chance of a significant leak each year, then over 30 years there would be more than a 25% chance that a significant leak would pollute the river. This is a high-risk situation.

Fortunately, over the last 30 years, society has developed many strategies to prevent fuel spills, including:

- Replace the single-walled tank with a double-walled tank.
- Include containment of 110% of the tank's capacity, so that even if the entire tank leaks, the fuel is captured rather than getting into the environment.
- Establish a rigorous inspection system and operational procedures to minimize spills.

Figure 1 illustrates how these prevention strategies reduce the risk of a spill in our example. The figure shows risk on a vertical axis—high risk at the top and zero risk at the bottom. The base case—a single-walled fuel tank filled adjacent to a river—is high risk. A 25% chance of spilling fuel into the river over the life of the tank is a high risk. As successive prevention strategies are introduced, the risk goes down. A double-walled tank, inside containment and monitored with a rigorous inspection program, is not zero risk—but the risk of a significant fuel spill is greatly reduced.

Besides taking measures to lower the risk of a fuel spill, a project developer may propose or the government may also require mitigation measures to limit the severity of a spill, if it happens, including:

- Move the fuel tank back one-half mile from the river.
- Have oil spill response equipment on site to clean up fuel as soon as it spills, before it can travel to the water.
- Establish a rigorous inspection system so that spills are identified right away, before they get worse or migrate to the river.

Figure 1. Effect of Risk Prevention Strategies

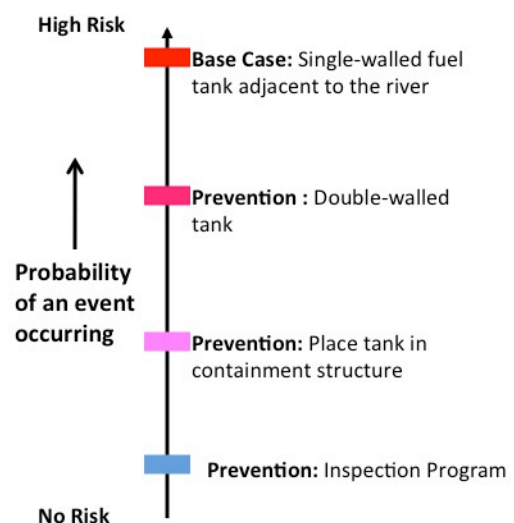
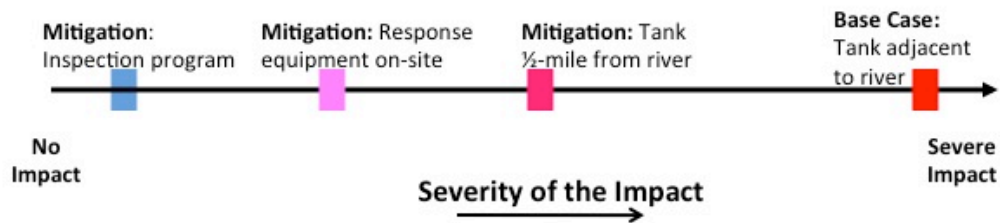


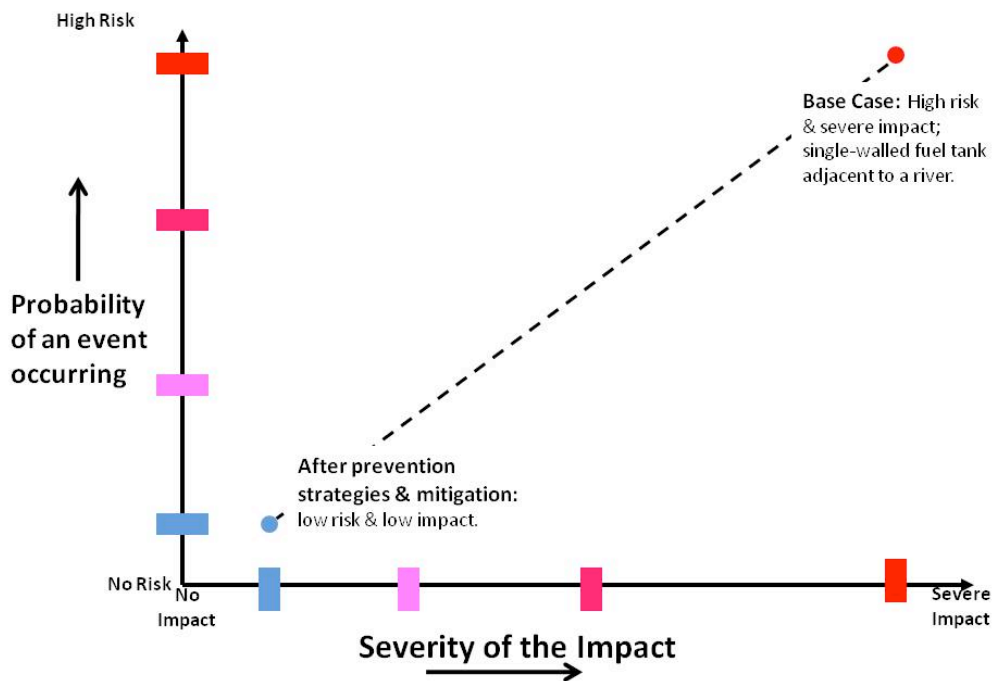
Figure 2 shows how mitigation measures might work in our example. The horizontal axis outlines the severity of the effects, worsening from the left to the right. Depending on the size of the spill, the slope of the ground, and other factors, moving the tank away from the river might mean no oil would go directly into the river. Having spill response equipment on-site might mean the spill could be cleaned up on the ground, before it has a chance to reach the river. Similarly, an inspection program could identify a leak while much of the oil was still in the tank. An oil spill occurring on the banks of a river is likely to be very harmful to the river water quality and fish habitat. But mitigation measures can sharply reduce those effects.

Figure 2. Effects of Risk Mitigation Strategies



Together, prevention and mitigation can transform a situation with high risk and severe consequences to a low risk of much lesser consequences. Figure 3 shows their combined effects.

Figure 3. Effects of Risk Prevention and Mitigation Strategies



The conceptual example explained above provides the framework for understanding one of the difficulties with constructing a pre-design ecological risk assessment: a pre-design, pre-permitting risk assessment can't include prevention and mitigation strategies that aren't known until there is a specific project design.

Section 3. Ecological Risk Assessment Methodology

The Ecological Risk Assessment Process

What is an Ecological Risk Assessment?

EPA developed the concept of ecological risk assessment in the 1990s, through a series of forums and workshops. In 1998, the agency published a set of guidelines for ecological risk assessment in the Federal Register. While there have been many scholarly articles written about ecological risk assessments since then, the EPA guidelines still define the process.

The EPA defines an ecological risk assessment as “The process that evaluates the likelihood that adverse ecological effects may occur as a result of exposure to one or more stressors.” A stressor is “any physical, chemical, or biological entity that can induce an adverse response.”⁶ To make the risk assessment more valuable, it specifies what harm is being risked or what needs to be protected. For example, the phrase, “There is a very high risk to salmon” is a scientifically ambiguous statement. It could mean a 10-foot reach of salmon habitat might be degraded, or it could mean there is a threat to the entire population in a watershed. For that reason, risk assessments evaluate the risk to a specific endpoint—which the EPA defines as “an explicit expression of the environmental value to be protected.”

The Ecological Risk Assessment Process

EPA’s guidelines for ecological risk assessment define a three-phase process: problem formulation, analysis, and risk characterization. While a complete description of EPA guidance is beyond this review, the stages are generally as summarized below.

- *Problem Formulation.* At this stage the analyst determines what elements in the ecosystem are at risk and need to be evaluated. The risk assessment will pick specific endpoints—that is, ecological conditions for which the risk assessment will define the risk. As noted above, EPA defines an assessment endpoint as “an explicit expression of the environmental value to be protected.” For example, salmon are valued ecological entities; reproduction and age class structure are some of their important attributes. Together, “salmon reproduction and age class structure form an assessment endpoint.”⁷ If an assessment included this endpoint, it would assess the risk that a project would decrease reproduction or disrupt the age class structure of salmon in particular streams or stream reaches.
- *Analysis.* At this stage, the risk assessment looks at the stressors—that is, the chemical or physical changes that a project would cause. The assessment comes up with a plan for analyzing the various pathways by which the physical and chemical changes could affect the endpoint, and then determines a plan for analyzing the effects. This phase is frequently the data-intensive part of the assessment. EPA guidelines are quite clear: “Even though the risk assessment focuses on data analysis and interpretation, acquiring the appropriate quantity and quality of data for use in the process is critical. If the data are unavailable, the risk assessment may stop until the data are obtained.”⁸ All of EPA’s

⁶ U.S. EPA. Framework for Ecological Risk Assessment. February 1992. Section 5. Key Terms, Page 37 and 38.

⁷ U.S. EPA. Guidelines for Ecological Risk Assessment. April 1998. Appendix B. Key Terms, page B-1.

⁸ Ibid, p. 7.

diagrams of the risk assessment process include a box off to the side of the diagram that reads, approximately, “As necessary, acquire new data.”

In most kinds of analyses, scientists tend to want more data. But the EPA’s guidelines have a clear implication for risk assessments: if the data are not good enough to allow analysts to come to a defensible conclusion, then they must gather more data or stop the analysis. Because of the wide range of ecological risk assessments, EPA’s guidance does not specify a particular detail or type of data that must be available. Decisions about what is necessary are left to the discretion of those doing a specific assessment.

- *Risk Characterization.* This last phase provides the conclusions about risk. Here analysts use information from the previous phases to estimate the risk to the assessment endpoints. For example, “there is little risk (or great risk) to salmon reproduction in this stretch of stream” would be a risk characterization. Analyst must also indicate their overall degree of confidence in the risk estimates—and, of course, must provide the chain of logic and data by which they came to their conclusions.

Engineering Risk versus Ecological Risk

Ecological risk assessments typically use, as a starting point for analysis, inputs that define the expected chemical and physical changes—in EPA terms, stressors—from a proposed project. Those inputs come from engineering evaluations. For example, an engineering evaluation might say that a proposed mine would have a discharge with a certain concentration of dissolved metals. The ecological risk assessment would take that concentration as a given and evaluate the ecological risk of a discharge with that concentration; the metal concentration in the water would be the chemical stressor to the system. Another example would be a mine evaluated as using a certain volume of water and not returning it to the ecosystem. The risk assessment would take that water loss as a given physical stressor and trace the ecological risk to the system from that amount of water loss.

But what about the risk that the mine won’t meet its projected physical and chemical parameters—that is, the project doesn’t perform as expected? These are engineering risks—the risk that a building will fall down, that a dam will fail, or that a water treatment plant will not produce water with the predicted quality.

Engineering risk evaluation is an iterative process (as is ecological risk assessment, to a certain extent). For example, government agencies cannot grant a permit for water discharge from a mine until they are convinced the discharge will meet permit standards; a company must prove to the agencies’ satisfaction that the proposed system will meet standards. During the design and permitting stages, all proposed mine processes may be designed and re-designed until they meet permit standards. Only after the agencies are convinced that the project design is adequate to actually meet the standards may the permitting process continue. Agencies will not proceed with an EIS for a project they believe cannot meet permit standards. There are numerous examples of permitting processes and even EIS processes being stopped until projects were re-designed to the point where the agencies believed they would meet permit standards⁹.

⁹ One example is the permitting process for the Pogo mine southeast of Fairbanks, which was stopped for an entire year while the company re-designed the facilities to meet EPA standards for volume of water discharge. The company moved all the facilities from the top of the ridge between Liese and Pogo creeks to a new location in the Liese Creek Valley to meet EPA requirements. Once calculations showed the new location would work for those standards, the process resumed.

To some extent, the ecological risk assessment process works that way as well. If the ecological risk analysis shows that a protected environmental value—an endpoint—could be unacceptably compromised, and an agency has the authority to deny a permit, the project would either stop or be redesigned.

In evaluating an ecological risk assessment, it is important to keep in mind the distinction between ecological and engineering risk. Put another way, if the engineering evaluation is wrong, then the inputs to the ecological assessment may be wrong: if the dam fails or the building falls down, then the conclusions of the ecological risk assessment may be undermined as well.¹⁰

Role of the Public in Ecological Risk Assessment

So far the discussion about ecological risk assessment has described it as an entirely technical process—science without the public having much of a say. But the public does have a number of opportunities to take part in the process. First, the assessment endpoints included in the risk assessment should represent an important benchmark to the public—and a level of change acceptable to the public. Imagine, for example, an assessment endpoint that is “maintain 95% of current or potential spawning habitat.” In some places around the country, the public might see an endpoint of 95% as too low; in other places, the public might consider it too high. Similarly, there might be public discussions about whether the endpoint should include potential spawning habitat as well as current spawning habitat.

Second, the public can review the science behind the ecological risk assessment. Typically, interest groups hire scientists to review risk assessments, but individual members of the public may of course also review assessments.

Finally, for those permits where an agency has the discretion to balance the risk to public resources against the applicant’s rights, the public may weigh in—using information from the risk assessment—to advise the agency whether the risk is acceptable and whether the permit should be granted or denied.

¹⁰ As an example of the difference between engineering and ecological risk assessment, the Lake and Peninsula Borough, in a letter (9/25/06) to the Alaska Department of Natural Resources, asked that the agency perform “A risk assessment concerning the failure of actual water quality at closure to meet predicted water quality.” That would be a request for an engineering risk assessment. An ecological risk assessment would take the water quality predicted in the engineering assessment as an input to trace the risk to important ecological resources.

Section 4. Examples of *Post-Design Ecological Risk Assessments*

Ecological risk assessments are frequently completed during the EIS process for mines in Alaska.¹¹ During the permitting and EIS processes, the specific details of the proposed project are known; government agencies will have forced the applicant to revise the engineering analysis so discharges and emissions appear to meet permit standards without undue risk of failure. A risk assessment conducted at this post-design phase can also take into account the prevention and mitigation strategies the applicant proposes or that governments will impose on the mine.

That last point—what government agencies will impose—is important. For example, if an ecological risk assessment analyzes water loss from mine operations, it matters how the authorizing permit is written. For example, taking water from a fish stream may pose risks to the fish, and presumably that risk would be greater during a drought, when the streamflow is lower. If the permit is written so the mine simply receives the right to a certain volume of water, then the ecosystem will bear the ecological risk of having too little water during a drought. But if the permit instead requires the mine to leave a certain flow in the stream, then the mine rather than the ecosystem will bear the risk of drought.

An ecological risk assessment is a data-intensive process. An assessment undertaken during the permitting phase gives government agencies the ability to gather critical data or to compel the applicant to gather that data. Two examples below show the importance of having the inputs to a risk assessment be well defined, and of having detailed project- and site-specific data.

Aqueous Tailings Disposal at the Kensington Gold Mine

The Kensington gold mine operates in an area of historic gold mining, 45 air miles north of Juneau, in southeast Alaska. Permits for the mine were issued in 2005, but litigation held up construction until the U.S. Supreme Court ruled on legal challenges in 2009. The mine developer proposed to place tailings in Lower Slate Lake. There are salmon downstream in Slate Creek, but a barrier downstream of Lower Slate Lake prevents salmon from reaching the lake. The lake has Dolly Varden char, which is a game fish in Alaska, and three-spine sticklebacks are also known to be in the lake.¹²

The permitting process for this mine included an ecological risk assessment to determine risks caused by the proposed disposal of tailings. That assessment was included as Appendix C of the Supplemental Environmental Impact Statement, evaluating the risks during both mining and reclamation. It looked at whether there was risk during mining when tailings would be placed in the lake, and whether there was risk for the long term, after the mine closed.

¹¹ See for example, Appendix C, Kensington Supplemental Environmental Impact Statement, Ecological Risk Assessment of Aqueous Tailings Disposal at the Kensington Gold Mine, December 2004. Also, Red Dog Mine Closure and Reclamation Plan: Evaluation of Ecological Risk within the Ambient Air/Solid Waste Permit Boundary (Exponent, 2008). Also, Draft Mine-Area Ecological Risk Evaluation, Prepared In Support of Red Dog Mine Closure Plan Development (Exponent, 2007).

¹² Appendix C, Kensington Supplemental Environmental Impact Statement, Ecological Risk Assessment of Aqueous Tailings Disposal at the Kensington Gold Mine. Tetra Tech, Inc. December 2004. P. C-12.

Phase 1. Problem Formulation: Picking Assessment Endpoints

Based on EPA's ecological risk assessment guidance, the first step in the process was problem formulation: picking risk assessment endpoints around which to structure the analysis. The analysts picked five primary endpoints and one secondary endpoint, summarized below.¹³ These reflect a relatively comprehensive set of endpoints for protection of fish, waterfowl, wildlife, and their predators—all of which are important to the public.

- *Dolly Varden char*. Re-establish or enhance a viable Dolly Varden char fishery in Lower Slate Lake at the end of mining. For this endpoint, the analysts needed to review the various conditions required for the survival, growth, and reproduction of Dolly Varden char. Part of the thinking behind this endpoint was that the fish might not survive when the Kensington developer was actually placing tailings in the lake. If they did not survive, the developer proposed to re-establish the fishery after the mine closed.
- *Secondary Endpoint—Dolly Varden char*. Protect Dolly Varden char during operation of the tailings facility. This endpoint includes protecting the survival, growth, and reproduction of the char, as well as the vegetation, macro invertebrates, and the three-spine sticklebacks necessary for the survival of the char.
- *Waterfowl*. Protect waterfowl during tailings operations and after the mine closes from lethal, mutagenic, reproductive systematic, or general toxic effects due to ingestion of metals in the lake water, or from benthic organisms or vegetation that had absorbed metals.
- *Terrestrial herbivores (for example, deer or moose)*. Protect terrestrial herbivores during tailings operation and after the mine closes from lethal, mutagenic, reproductive systematic, or general toxic effects due to ingestion of chemicals from the water and in vegetation along the margins of the lake.
- *Terrestrial omnivores (for example, black bears)*. Protect terrestrial omnivores during tailings operation and after the mine closes from lethal, mutagenic, reproductive systematic, or general toxic effects due to ingestion of chemicals in water and food affected by the tailings facility.
- *Higher-order predators (for example, wolves, river otters, and bald eagles)*. Protect higher-order mammalian and avian consumers (e.g., predators) during tailings operation and after the mine closes from ingesting water and contaminated prey that might result in lethal, mutagenic, reproductive, systematic, or general toxic effects due to metal concentration.

Phase 2. Analysis

The analysis for risk assessments start with the physical and chemical changes in the ecosystem the project could cause—in the language of the EPA, the stressors. The most important inputs for the Kensington analysis were the chemical characteristics of the mine discharge. It was critical to know the metal concentrations and pH in the water and tailings that the Kensington developer proposed to place in the lake. It was also important to know the volume of tailings and water discharged by the mine.

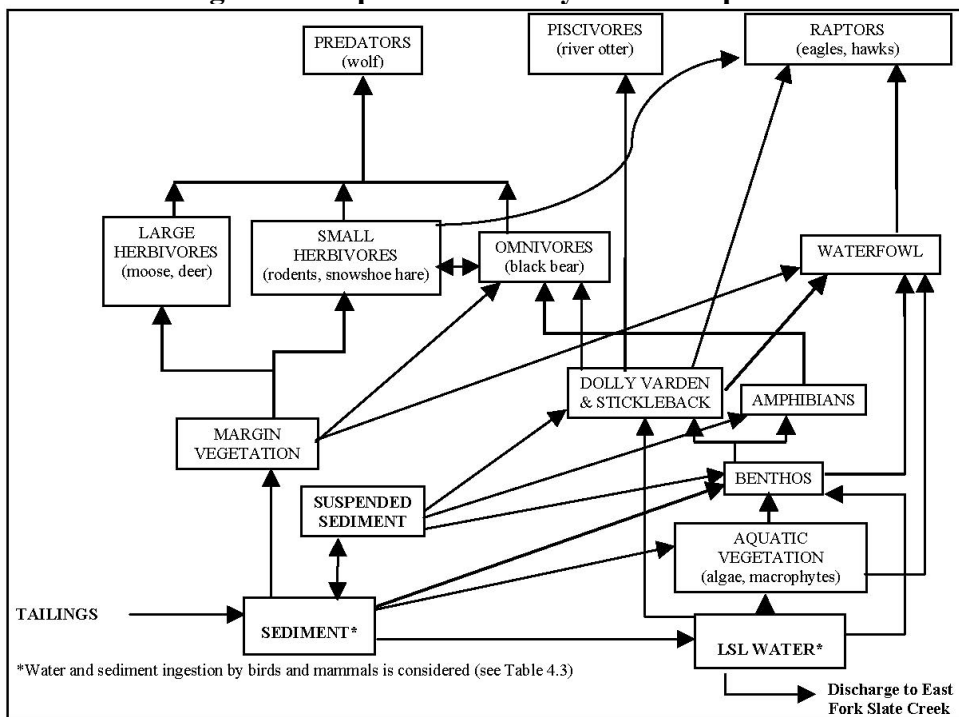
¹³ The assessment analysts actually picked a management goal for each endpoint, and then a more scientific assessment endpoint that is a proxy for the management goal. For brevity, the two are summarized together.

The analysts took these stressors and began a screening process to determine which had potential to significantly harm the fish and wildlife specified in the assessment endpoints. To assess the potential ecological concerns, the screening process used a combination of project-specific testing, site characteristics, and national studies. Project-specific tests included measuring metal concentrations and pH in Kensington test-tailings created from ore samples, and measuring the bioaccumulation of metals from synthetic Kensington tailings in macro invertebrates. The analysts also looked at site-specific characteristics, such as water quality of the lake.

Based on this screening process, the analysts selected four chemicals for further analysis: aluminum, chromium, pH, and Total Suspended Solids. They then calculated the cumulative exposure fish and wildlife could have, through any of a complicated set of pathways, as shown in Figure 4. For example, eagles or hawks could be exposed to the metals of concern by eating waterfowl. Waterfowl could be exposed by eating vegetation on the lake margin, benthic organisms, or aquatic vegetation (like algae); by direct contact with lake water and sediment; and by eating fish in the lake.

The assessment looked at each link to see how metals would be passed through the ecosystem. It looked at the likely accumulation in the fish themselves, based on their exposure to lake water, bottom sediment, and suspended sediment. It calculated the cumulative exposure and compared that to various criteria for toxicity.

Figure 4. Exposure Pathways and Receptors



Source: Figure 2.2, Conceptual Site Model of Exposure Pathways and Receptors. Kensington SFEIS, Appendix C. Ecological Risk Assessment of Aqueous Tailings Disposal at the Kensington Gold Mine. December 2004; p. C-18.

Phase 3. Risk Characterization

Risk characterization is the final phase in ecological risk assessment, comparing the results of the analysis for the endpoints and drawing conclusions about risk and the level of uncertainty in the conclusions for both physical and chemical stressors. For the Kensington mine assessment, the physical stressors were the total suspended solids and the deposition of tailings (sedimentation), and the chemical stressors were the metal concentrations and pH in the tailings and water.

For the proposed deposit of tailings in Lower Slate Lake, the ecological risk assessment included a detailed analysis for each of the endpoints listed earlier. In general, the assessment concluded that during mine operations “there is significant uncertainty whether the [tailings facility] would support fish population during operations.” But it concluded that after reclamation the lake “should eventually provide better long-term conditions for Dolly Varden char than the current conditions in [Lower Slate Lake], although data show this level of recovery could require more than 50 years.” Overall, it concluded that in general the risk to other species (other endpoints) was low.

Conclusion: Project-Specific Data Requirements for Kensington Tailings Disposal

The ecological risk assessment for disposal of tailings at the Kensington Gold Mine provides an excellent example of data requirements for a risk assessment. Much of the data that is important to a risk assessment is project-specific and cannot be known in detail until a developer has submitted a project design.

Project-Specific Input for the Ecological Risk Assessment

- The most important inputs for the Kensington tailings assessment were the geochemical characteristics of the tailings and water discharge into Lower Slate Lake (i.e., the metal concentrations and pH). The Kensington mine uses a floatation process to extract the gold from the ore. The metal concentrations and pH in a floatation process discharge differ between mines, depending on the chemistry of the ore and how the mine engineers the processing. The process will also differ depending on the gold recovery objectives and what other metals the company includes in the ore concentrate. Some metals, like zinc, add to the ore’s value, while others subtract from what a smelter is willing to pay for the concentrate. Different floatation processes have different objectives, different costs, and remove more or less of the gold or other metals and result in discharges with different characteristics. The floatation process for Kensington was engineered for the specific geochemical circumstances of the Kensington ore—and for the company’s economic objectives.

To engineer the process for Kensington, the mining company ground up small representative ore samples and ran them through small-scale versions of the process they would use. It then tested the discard—the tailings and the water—to determine the chemical characteristics of each. The government permitting agencies scrutinized the results of the tests. After the agencies agreed that the tests represented a reasonable proxy for the discharge from the actual mine, the ecological risk analysts used these tailings/water characteristics as the input to the assessment.¹⁴

¹⁴ The agencies’ determination of the most representative discharge was the result of detailed review and iterations of mine design. It was included as Attachment A of the EIS for the mine for public review. The ecological risk assessment used these inputs, and noted “the decant water generally represents the worst-case water for the lake...” and explained the reasons. P. C-27 *ibid*.

- Other project-specific data important as input to the analysis included the project's throughput and water budget. This information determined the flow rate of tailings and water that would be put into the lake and withdrawn from the lake for processing.

Site-Specific Information Gathered for the Ecological Risk Assessment

- Physical characteristics of Lower Slate Lake. The assessment looked at the natural metal concentrations and pH, and then calculated what the resulting concentration would be after the Kensington discharge and mixing. These post-mixing metals' concentrations depended on the tailings flow rate, but also on the bathymetry and natural flow rate into Lower Slate Lake, on pre-mining water quality, and on pre-mining metal concentrations of the lake sediment. This information was important because it defined how the project would change Lower Slate Lake.
- Fish and wildlife characteristics of Lower Slate Lake. These characteristics included the location and extent of Dolly Varden char spawning habitat, light penetration characteristics of the lake, fish populations and use, benthic invertebrate populations, wildlife use, and other characteristics. All this was needed so analysts could define the pathways in Figure 4 above, and to calculate how the metal concentrations moved through the pathways.
- Vegetation colonization potential of the tailings. Analysts conducted habitability tests on Kensington mine tailings, using marine organisms and freshwater organisms. They compared the results of the tailings studies with those conducted on natural sediments, to show whether and how fast vegetation and benthic organizations would naturally re-colonize the tailings.
- Bioaccumulation test. Scientists did specific work in 1999 to test the bioaccumulation in benthic organisms of metals in Kensington tailings. Benthic organisms are critical, because they are the foundation for the food chain.

The results of the Kensington tailings risk assessment—and confidence in those results—depended on this project-specific and site-specific information.

Assessment of Red Dog Road Fugitive Dust Risk

The best-known ecological risk assessment in Alaska was done for the Red Dog mine road, which runs 52 miles from the Red Dog lead-zinc mine to a port on the Bering Sea. The Red Dog mine trucks its concentrate down the road from the mine to the port, and from 1989 (when the mine opened) until 2001 the haul trucks were uncovered. As a result, metal-laden dust accumulated along the road. In 2001, the National Park Service published a study that found a high level of metal concentrations in tundra along the road. After the report was published, the public became very concerned about the consequences of those metals for people and the environment. In particular, residents of the nearby villages of Kivalina and Noatak worried about the health of the fish and wildlife exposed to the dust, and about whether people were receiving unhealthy doses of heavy metals from eating contaminated subsistence foods.

Responding to those concerns, the Environmental Public Health Program of the Alaska Department of Health and Social Services got involved in testing subsistence foods, and the Alaska Department of Environmental Conservation also investigated the issue. Teck Cominco,

the mine operator, contracted for both a human health risk assessment and an ecological risk assessment. The contractor's report was completed under the jurisdiction of and was reviewed by the Alaska Department of Environmental Conservation.

The final report, *DMTS Fugitive Dust Risk Assessment*, prepared by Exponent, was published in 2007. (The Red Dog mine road is officially known by the somewhat awkward name of Delong Mountain Transportation System, or DMTS.) Consistent with EPA guidelines, analysts looking at the effects of fugitive dust from the Red Dog mine went through a similar set of processes and steps as described earlier for the assessment of Kensington mine tailings disposal: problem formulation, analysis, and risk characterization.

The assessment of fugitive dust did differ from the Kensington example, because it was an assessment of a mine facility already operating, rather than just planned. In that case, scientists could go out and look at existing site-specific data, rather than having to rely on tests and models derived from site-specific data. But the fugitive dust assessment still required a large amount of information that would have been difficult or impossible to formulate before detailed design information was known.

New Information Collected

Based on sampling and screening, the ecological risk analysts looked at the risk from fourteen metals: aluminum, antimony, arsenic, barium, cadmium, chromium, cobalt, lead, mercury, molybdenum, selenium, thallium, vanadium, and zinc.¹⁵ Although there was a significant amount of information already available, analysts collected a significant amount more for the risk assessment.

The fact sheet from the assessment describes information gathered: "Data were collected in the marine lagoon, stream, pond, and tundra environments surrounding the port, road, and mine. Some data were collected for use in the human health risk assessment, some were collected for use in the ecological risk assessment, and some were collected for use in both. Samples of soil, water sediment, and plant and animal tissues were collected from these environments and analyzed to determine metal concentrations. The foods eaten by the representative receptors were identified so that samples of those foods could also be collected to determine metal concentrations. Thus sampling included moss, lichen, willow, birch, sedge grasses, insects in land and water environments and shrews and voles." Fish tissue samples were collected as well.

The fact sheet goes on to summarize information gathered "to evaluate the health of plant and insect communities. Plant communities were evaluated in land (terrestrial) and water (aquatic) environments, including coastal plain and tundra, hill slope, stream and pond, and coastal lagoon communities. These plant communities were studied to determine whether there were any effects on community structure (for example, species diversity and abundance) and health of species within the communities at different distances from the port, road, and mine. Insect communities were evaluated in streams and lagoons. Samples of the aquatic insect communities were collected from streams to determine their diversity and abundance in comparison to similar

¹⁵ Factsheet: Risk Assessment of Metals in Dust from Red Dog; prepared by Exponent® for Teck Cominco Alaska Incorporated, November 2007. Page 7. Available on the DEC website: <http://dec.alaska.gov/spar/csp/sites/reddog.htm> (10/25/11).

streams offsite. Sediment (bottom mud) samples from lagoons were collected for laboratory testing with insects to determine if sediment could affect health of lagoon insects.”¹⁶

The Public’s Role in Red Dog Assessment

This risk assessment was unusual in that it was prompted, in part, by concerns of the residents of Noatak and Kivalina—and as a result the public engagement was more extensive than usual.

- 2001. Initial site characterization began and initial contacts were made with villages and interest groups.
- 2002. A background document was prepared that included a preliminary conceptual site model—that is, a model explaining pathways by which contaminated soils or vegetation could harm fish, wildlife, and people, similar to the one shown in Figure 4. That model was important because it provided the framework to show what data were needed. The model was discussed during public meetings in Kivalina and Noatak.
- 2003. Village meetings were held to review and discuss the work plan to gather data for the risk assessment.
- 2005. A draft risk assessment was distributed and public comments were requested.
- 2007. A final risk assessment, incorporating public comments, was published.

Ecological risk assessments done as part of an Environmental Impact Statement typically receive little attention during the public scoping process. A draft assessment is distributed with the draft EIS for public comment, and then the final EIS is published. The public had more opportunities to comment on the Red Dog road fugitive dust assessment, and because it was not a part of a larger issue, like mine permitting, it received more in-depth attention from the villagers and from some interest groups. A goal of the study was to instill public trust in its conclusions, so analysts provided the public with more up-front discussion than usually occurs.

Conclusions of the Red Dog Road Risk Assessment

One of the most important conclusions of the human health portion of the assessment was that “It is safe to continue harvesting subsistence foods in all areas without restrictions.” Conclusions specific to the ecological risk assessment included:

- In most cases, the potential for harmful effects to occur in the environments surrounding the road, port, and mine were considered to be low.
- No harmful effects were observed or predicted in the marine, coastal lagoon, freshwater stream, and tundra pond environments, though the potential for effects to invertebrates and plants could not be ruled out for some small, shallow ponds found close to facilities within the port site. However, no effects were observed in these port site ponds during field sampling.
- The likelihood of risk to populations of animals was considered low, with the exception that risks related to lead were predicted for ptarmigan living closest to the port and mine, which may affect ptarmigan populations in those localized areas.¹⁷

An important factor that increased the credibility of this risk assessment was that analysts were able to use actual, detailed data from the site, rather than having to rely models and scientific conjecture from other studies.

¹⁶ Ibid, p. 9.

¹⁷ Ibid, p. 12-13.

Section 4. Pre-Design Ecological Risk Assessment: Risks of Large Scale Mining in the Bristol Bay Watershed

Background

In October 2010, The Nature Conservancy published *An Assessment of Ecological Risk to Wild Salmon Systems from Large-scale Mining in the Nushagak and Kvichak Watersheds of the Bristol Bay Basin*. The conservancy said its purpose was “to analyze and portray the potential risks to globally significant salmon resources of the Nushagak-Mulchatna, and Kvichak river drainages (proximal headwater areas) as a result of large-scale mining and associated facilities.”¹⁸

The document attempts to scientifically assess the ecological risks of the Pebble mine project to Bristol Bay salmon. It is the first ecological risk assessment published for a project in Alaska before the developers have submitted a project design.

The Pebble project is an advanced mineral exploration site on state-owned land within the Bristol Bay watershed in southwest Alaska. It is exploring the potential to develop a major deposit of copper, gold, and molybdenum. The mining company is expected to propose a large open-pit mine in the area. But Bristol Bay is also home to the world’s largest red salmon run and supports important commercial, subsistence, and sport fisheries.

Previous sections of this report have described the detailed site-specific design and environmental information analysts use to reach conclusions about ecological risk—after the developer has proposed a mine design and when government agencies are evaluating the plan and deciding whether to issue permits. This section of the paper looks at The Nature Conservancy’s pre-design ecological assessment, to evaluate whether such an early assessment can make credible scientific conclusions about risk from proposed mining projects. We look in detail at five ecological issues covered in the conservancy’s assessment:

- Acid rock drainage
- Water withdrawal
- Culvert impacts
- Fugitive dust
- Dam failure

We chose to look at The Nature Conservancy’s coverage of acid rock drainage and water withdrawal because preventing water impacts on nearby streams is typically the most important issue for mine permitting. We look at the coverage of culvert installation because it provides a good opportunity to evaluate how omitting mitigation and prevention strategies affects the findings. Fugitive dust is, like acid rock drainage, another chemical issue affecting water quality. Finally, we examine the assessment’s coverage of potential dam failure because that issue appears to have captured the imagination and fears of at least some of the public.

¹⁸ Page 1.

Basis for Nature Conservancy's Assessment

In 2006, Northern Dynasty Minerals Limited, a junior mining company, applied to the Alaska Department of Natural Resources for water rights for the planned Pebble mine. The department's regulations require that when water withdrawal would involve a dam, an application to construct the dam be included as well. Thus, Northern Dynasty's water rights application included an application to construct dams, as well as a conceptual mine design. The water rights and dam applications received a date stamp and nothing more from the department, which suspended processing pending a full mine application and the start of the Environmental Impact Statement process. The 2006 conceptual design included only limited information about water use and dam construction, and it was one of the many alternatives then being considered for the Pebble project.¹⁹

In 2007, Anglo-American PLC—an international mining company—purchased 50% of the Pebble project and formed Pebble Limited Partnership, a 50:50 partnership between a subsidiary of Anglo-American and Northern Dynasty Minerals. The new partnership announced soon thereafter that it was no longer actively considering the 2006 design. It has not announced a reason, though presumably economic and environmental feasibility considerations played a part. In informal conversations with the author over the past few years, partnership employees have indicated the company is considering multiple alternatives for a design, but is no longer considering the 2006 alternative.²⁰

To analyze and portray the risks of the Pebble project, The Nature Conservancy used the obsolete 2006 conceptual design. Although the developers were no longer considering that design, in 2010 it was the only publicly available conceptual design for the project.²¹ The 2006 design lacked detail, including most of the prevention and mitigation strategies that developers would include—and government would require—of a mine.

The conservancy's assessment acknowledges that “no comprehensive mine management plan (MMP) for mining in this area has been submitted for permitting or released to the public. Generally, a MMP is developed prior to mining commencement and includes identification and description of mining activities, particulars of the implementation of the management systems to address environmental issues; a plan and costing of closure activities . . . and other information as required.”²²

¹⁹ From author's conversations with Pebble employees, the alternative was labeled MDC (mine design concept) 25, the implication being that there were at least 24 other concepts. Since 2006, the company has also considered other alternatives and designs.

²⁰ Some people believe that the 2006 water rights application was not necessarily intended to represent a realistic mine plan, but rather that it was submitted to the agencies to establish a priority date for future water rights. Generally, earlier applications have priority over later applications for the same water (though there are exceptions). Some people think Northern Dynasty applied for water rights to help it in a future court battle with environmentalists, whom it believed would apply for rights to the same water. If the mining company's application was primarily part of a legal strategy, that strategy would have required the company to apply for the maximum water it could conceivably justify. Then, a later application, based on a detailed project design, might have a water budget calling for less water. These sentiments are widely shared (including by this author), but have never been confirmed by any official of the company.

²¹ On February 17, 2011, Northern Dynasty published another preliminary design for the proposed Pebble mine, with more detail than the 2006 conceptual design and proposing a different tailings location. Two weeks later, the CEO of Anglo American effectively distanced Anglo from Northern Dynasty's new design. In an Anchorage speech, she said the Pebble Partnership “is still studying multiple options. . . and the Partnership does not have a preferred option,” and that the CEO of the partnership and his team would “engage in further consultation in advance of taking any proposal to permitting.” Cynthia Carroll, CEO Anglo American PLC, speech to Resource Development Council of Alaska, March 3, 2011.

²² P. 2

The conservancy’s assessment directly addresses the question of using a design that might not be the basis for permitting: “Although this particular design may or may not form the basis of actual mine permitting in the future, this design does provide a conceivable scenario for how a large-scale mine might be constructed and operated for this prospect, and thus is a suitable proxy for understanding the risks of such activity in these watersheds.”²³ It goes on to say, “Although various details of a mine may change prior to final permitting, risks from various physical and chemical stressors are likely to be similar for any large-scale mine in this area.”²⁴

Is the Assessment Intended as Illustrative or Predictive?

Because the conservancy’s study is a pre-design risk assessment, we need to address a question before moving into a detailed analysis: is the assessment intended as illustrative or predictive? Does it list risks that *might occur*? The assessment might simply be intended to illustrate potential risks that the public and permitting agencies should investigate during the permitting process—risks that a detailed mine design might (or might not) substantially minimize or eliminate. In that case, it could provide a list of issues to investigate during permitting. Or does the assessment attempt to predict what *will occur*—that even without a final mine design, the assessment is intended to specify the risks and the ecological consequences?

There is at least some evidence in the assessment to support either conclusion about its purpose. The preface and introduction to the report indicate that it analyzes potential risks. For example, the assessment says it is “designed to analyze and portray the potential risks to globally significant salmon resources of the Nushagak-Mulchatna, and Kvichak river drainages (proximal headwater areas) as a result of large-scale mining and associated facilities.”²⁵ In other places as well, the risks are discussed as “potential.”

But elsewhere the risks are described as “inevitable,” and the assessment says, “Risks identified in this scenario [the scenario used for the risk assessment] and found to be associated with mines *regardless of their design* . . . apply to any large mine development in the region, whether it be at the Pebble prospect or any number of other mining claims currently identified and/or under exploration in the Nushagak and Kvichak watersheds (emphasis added).”²⁶

The author also attended a 2011 presentation about the risk assessment that the conservancy made to the Lake and Peninsula Borough Assembly.²⁷ The presentation made it clear that the conservancy concludes the risks identified in the assessment—or very similar risks—are inevitable. Also, discussion at the assembly meeting turned to questions about how the assessment had influenced the conservancy’s decision to oppose the Pebble mine project. Representatives of the conservancy said that the level of risk outlined in the assessment was unacceptable and was an important reason the conservancy decided to oppose the project.²⁸

²³ Page 1

²⁴ Page 2

²⁵ Page 1.

²⁶ Preface.

²⁷ April 18, 2011

²⁸ Representatives of The Nature Conservancy handed out an undated resolution at the April 18, 2011 meeting of the Lake and Peninsula Borough Assembly, and said it had been passed by the conservancy’s board. It read, in part, “Whereas, for the last four years, the Conservancy has undertaken rigorous scientific investigation at a cost of roughly \$2.5 million, including commission of several peer-reviewed independent reports [including the assessment that is analyzed here], to assess the potential risks to these resources caused by large-scale mining in these watersheds[;] Whereas, based on our understanding of the risks and the state of current, proven mining technology, large-scale mining in these critical watersheds at this time presents an inappropriate risk to the salmon systems of the region.”

Overall, then, the balance of evidence is that The Nature Conservancy believes the risks to salmon cited in its assessment are inevitable, as a result of the Pebble mine project or any other any large-scale mine developed in the Bristol Bay watershed. The remainder of this section examines five areas of risk addressed in The Nature Conservancy's ecological risk analysis.

Acid Rock Drainage

There is a rich academic and government literature describing acid drainage from some mines, described as acid rock or acid mine drainage.²⁹ The Nature Conservancy's assessment summarizes some of that literature to demonstrate the common occurrence of the problem, especially at long-abandoned mines. There is a similarly rich literature on the effects of acid drainage on aquatic resources. As the assessment correctly summarizes, "Scientific literature is plentiful with studies that quantify the adverse environmental effects" of acid drainage on aquatic resources.³⁰

Having established that acid rock drainage can occur at mines and has serious adverse environmental consequences for streams, fish, and aquatic life, conservancy's assessment turns to the next question: whether such acid drainage will occur at the proposed Pebble mine.

The assessment begins by establishing that ore at the Pebble site is potentially acid generating. It summarizes a 2006 memo that reviewed the geochemical characterization of ore from 399 samples, published by Northern Dynasty in 2005. The memo concludes that 95% of those samples have a ratio of acid-producing to acid-neutralizing minerals that indicates the ore is potentially acid generating. Pebble's exploration database now numbers in the tens of thousands of samples, and staff at the Pebble mine have told government agencies that the additional samples support the conclusion that most of the ore in the Pebble deposit is potentially acid generating. Based on this information, it appears that if crushed and left exposed to oxygen and water, the ore would likely produce acid run-off.³¹

The assessment also references two reports critical of the mining industry. Maest et al. (2005) concludes there is significant uncertainty in predicting future water quality from mines, and Kuipers et al. (2006) concludes that EIS predictions of acceptable water quality are often overstated. The Kuipers study finds a number of causes for those inaccurate predictions,

²⁹ The term acid mine drainage (AMD) was first used to describe problems at coal mines in the United Kingdom. Many people now substitute the term acid rock drainage (ARD) to reflect the fact that the acid drainage can occur naturally, and that the problem can occur at other large-scale ground disturbances such as transportation or landscaping. There is a good discussion of the use of the two terms in Wikipedia (en.wikipedia.org/wiki/Talk:Acid_mine_drainage). From that website (on 9/13/11) "It is important to note that there is also a political subtext to this issue. Those who are favorable to mining tend to use the more generalized term ARD intending to diffuse away responsibility. In contrast, environmentalists and mining opponents often insist on AMD, wishing to strictly associate acid drainage with mining activity. In North America, common usage has shifted from AMD to ARD, except among environmentalists groups." The Nature Conservancy uses AMD in its assessment. In this paper, the author uses ARD because he comes from a background as a regulator in which ARD was the common usage. The two terms are interchangeable with respect to this report.

³⁰ Page 54.

³¹ The industry uses the terms *Potentially* Acid-Generating (PAG), and *Not Potentially* Acid Generating (Non-PAG) to describe the two ore types. The word "potentially" in these terms recognizes that management techniques may be used to prevent acid generation from ore with high acid-generating potential. Not all techniques work in all situations. However, there are numerous mines with PAG rock in their tailings that have prevented acid from forming, and others that have prevented acid from reaching the environment and harming downstream water quality.

including incomplete geochemical characterization and incomplete hydrologic information, and then concludes that proximity to a water source makes contamination more likely.

Given this information, the conservancy's assessment concludes: "...for the proposed mine, the understanding that the mine would be developed in an area with moderate precipitation (>36 inches of precipitation per year), a high water table, numerous small streams, and over geological formations that are susceptible to groundwater movement, makes AMD [acid mine drainage] highly likely and a high risk proposition" and that "*it is assumed* that AMD will be formed at the proposed mine (emphasis added)."³²

It is important to understand the chain of logic in the assessment. It describes certain environmental characteristics that make preventing or containing acid formation more difficult: proximity to water, a high water table, and significant groundwater movement. It cites a study asserting that when Environmental Impact Statements predict mines won't cause acid formation, those predictions are often overstated. Then, without evaluating whether any mitigation and prevention strategies would work in the locations described in the 2006 conceptual mine design, the assessment assumes acid drainage will form at a Pebble mine site.

The assessment also assumes that the acid drainage will not be captured, and that it will be pH 4 (highly acidic). Based on literature describing historic and long-abandoned mines, the assessment concludes that a Pebble mine would uncontrollably discharge pH 4 water. But the mines discussed in the assessment operated between 60 and 180 years ago, when there was no government environmental management or required mitigation.³³

Finally, the assessment assumes this contaminated flow would include all flows of water from the Pebble site. For the South Fork Koktuli River, these would amount to 7.2 cubic feet per second (cfs) during winter low flow and 114 cfs during May. For the North Fork Koktuli, the flow would be from 2.6 to 40.7 cfs. In other words, the risk assessment assumed large volumes of contaminated water would flow uncaptured from the site. It estimates "Instream pH levels from [acid mine drainage] below 5 could occur up to 30 miles from the mine. Low pH would result in fish kills and benthic community impacts."

To summarize, in the absence of a specific proposed mine location, a detailed mine plan with prevention and mitigation measures, and without investigating government requirements for dealing with acid formation, the risk assessment assumed catastrophic failure consistent with the failure from mines far in the past, at a time without environmental laws or management.

Preventing or containing acid formation is one of the most important issues at any mine, and is a focus of both federal and state permits. The assessment's conclusion that there would be significant uncaptured acid drainage from a Pebble mine is part of the basis for conclusions about ecological risks in other sections of the assessment. But there are a number of errors in the assessment's means of reaching its conclusions, mostly because of assumptions analysts made in the absence of project-specific information.

³² P. 100. Also, as explained in footnote 29, the terms ARD and AMD have the same meaning in this report.

³³ According to the literature cited in their report, The Nature Conservancy made the assumption of pH 4 effluent after considering effects on Copper Brook Creek from the Phillips Mine, New York, abandoned approximately 1880 (Gilchrest et al, 2006); Ore Hill Mine discovered 1834 and permanently closed 1915 (USFS 2009); Mount Perry Copper Mines Australia, mined approximately 1870s; an unspecified copper mine in Turkey (Mahiroglu et al 2009); and the Penn Mine in California, mined beginning 1861, abandoned 1953 (Bambic et al, 2006).

Error 1: Ore v. Tailings. Samples from the Pebble site confirm that most of the ore is potentially acid generating. But it isn't unprocessed ore that is put into the environment. It is the tailings—the leftovers after the ore has been processed and the valuable metals extracted—that go into the environment and can pose risks to land and water. Understanding the make-up of the tailings is important for predicting their environmental effects. The acid-generating potential of the ore is related to but is not the same as the acid-generating potential of the tailings.

From presentations Pebble developers have made to government agencies, it appears they intend to use a milling process (floatation) to separate the heavy metals and sulfide from the remainder of the ore. If the company is successful, the milling process will generate concentrate (copper and other target minerals) and tailings. The presentations and the 2006 application indicate that the tailings themselves will be in two streams: “inert” (not-potentially acid generating) tailings making up 97% of the volume, and potentially acid-generating tailings making up 3%.

Floatation is a common process, and in Alaska it is used at the Pogo, Greens Creek, Kensington, and Red Dog mines. Without the detailed test that would be evaluated during permitting for a Pebble mine, it is not possible to assess the extent to which the developers will succeed in eliminating acid-generating potential and heavy metals from the majority of the tailings. But without such data, it is also impossible to conclude that the company will fail.

Also, there is a huge difference between providing conservative management to prevent billions of pounds of acid-generating tailings from leaching contaminated water into the environment and managing perhaps 3% of that amount, surrounded by non-acid generating tailings. Proposed methods of protecting a small portion of tailings from affecting the environment are common components of mine designs.

Error 2: Focusing on Characteristics of a Site That Will Not be Used. The mine site conditions described in the assessment—“high water table, numerous small streams and over geologic formations that are susceptible to groundwater movement”—may exist at Site A, the larger of the two tailings locations included in Northern Dynasty's 2006 applications. But they may not exist at other sites in the Pebble project area. The developers have indicated they are no longer considering Site A for a tailings location. So the assessment's conclusion that specific hydrologic characteristics make Site A inappropriate for tailings storage has little relevance; specific characteristics of sites that may be proposed in a future mine design submission are unknown right now.

Error 3: Overgeneralization of Site Information. The 2006 applications identified two potential tailing sites. There is no evidence that the potentially risky conditions described for Site A (above) exist at the second site, Site G, which appears to be a typical mountain valley. No available evidence suggests that Site G has unusual depth to bedrock, high water table, or high susceptibility to groundwater movement. In fact, the 2006 application provides some evidence for the opposite. The water rights applications request all water upstream of the tailing dams. For Site A, groundwater would be approximately one quarter of the total water, but only 1/340 of the total for Site G.³⁴ This relatively small amount of groundwater in the Site G application indicates that the conditions described for Site A don't exist at Site G.

³⁴ The Site A request is for 51 cubic feet/second (cfs), of which 12 cfs is groundwater. Site G request is for 34 cfs, of which only 0.1 cfs is groundwater.

Error 4: Departure from the Literature. Even if the location ultimately proposed for the mine were to have the environmental conditions described for Site A—including high water table and formations susceptible to groundwater movement—the literature on acid rock drainage does not preclude locating a mine in those conditions. The literature does recommend careful and complete geochemical analysis, baseline water quality, and multiple back-up mitigation to ensure that acid-generation or significant metals leaching is avoided, and if it occurs, is caught before it affects water quality. It might be more difficult to locate a mine in these conditions, and high standards, extensive baseline information, and extensive testing and monitoring would be appropriate. Without much more information than is currently available, it is not possible to conclude that a mine design would succeed in a location with conditions similar to those at the 2006 proposed Site A. But without knowing how the mine’s waste would be managed and without the necessary supporting data, it’s also not possible to conclude it would fail. The conclusion that environmental conditions like those at Site A would inevitably lead to acid drainage does not have a basis cited in the literature.

Error 5: Omission of Prevention and Mitigation Techniques. The conservancy’s assessment gives no consideration to mine design or government-mandated prevention and mitigation requirements. There are numerous techniques designed to keep potentially acid-generating tailings sequestered from oxygen (which prevents the acid from forming) and mitigation techniques that prevent acid that has formed from reaching the environment. For example, the Pogo and Greens Creek mines separate tailings by their acid-generating potential, encase a portion of the tailings in a cement mixture, and put these tailings underground (to prevent acid formation). The Kensington mine ships most heavy metals and sulfide minerals off-site. The Pogo, Greens Creek, and Kensington mines are underground, and these techniques would likely be unavailable to an open-pit operation such as that proposed for the Pebble site. But the point is, there are risk prevention techniques to prevent acid formation, and mitigation techniques to prevent any acid from leaving the site. Until the Pebble developers propose a design and there is appropriate data to evaluate that design, it is not possible to draw conclusions about their ability to prevent acid rock drainage from forming, or reaching the environment if it does form.³⁵ But the issue government agencies discuss most during permitting for mines is the potential for acid-mine drainage (and metals leaching). The assessment’s conclusion that acid-generating ore would turn into acid-generating tailings and be generally distributed, without significant management, is unwarranted. Such a mine could not be legally permitted.

Error 6: Level of Uncertainty. The conservancy’s assessment also addresses the question of the uncertainty of its conclusions. It concludes, “Based on historical information from other hard rock mines, there is a high certainty that [acid mine drainage] will develop during the life of the mine and affect downstream water bodies.” The language in which the assessment gives itself a high degree of certainty is technically restricted to acid-formation itself, not the volumes or the uncontrolled release. But readers are likely to infer that this level of certainty applies to the overall issue—formation, volume, and uncontrolled release of acid drainage. It is difficult to find any justification for that certainty, given the analytical errors discussed above.

³⁵ Still, it is surprising that the assessment ignores the proposed prevention strategy—tailings separation—included in the 2006 application: dividing tailings into 97% inert and 3% potentially acid generating. Without the detailed testing and design information missing from the 2006 applications, it is not possible to estimate the success (or failure) of this technique.

Water Withdrawal

In 2006, Northern Dynasty applied for the right to use all the water in the mine area it was considering at the time. That included surface and groundwater within portions of the South Fork of the Koktuli drainage, a tributary of the North Fork Koktuli River, and Upper Talarik Creek.³⁶ The Nature Conservancy's assessment takes the water volume requested in the applications and traces the effects on salmon habitat of losing that amount of water. Those effects include direct loss of habitat at the mine site, and decreased flow and changes in substrate, velocity, temperature, and other measures downstream.

This paper does not evaluate the impact methodology the Nature Conservancy used to trace the effects on habitat, flow, or environmental parameters of losing that volume of water. Instead, it evaluates the assumptions used in the assessment.

Alaska statutes require a government authorization before a company or individual *uses* water, but that definition includes diversions. Alaska Statute AS 46.15.180(a)(1) provides that “A person may not construct works for an appropriation, or divert, impound, withdraw or use a significant amount a water without a permit...” If a mine uses water and then returns it to the stream, the mining company still needs a permit or water right. If the company diverts a stream without changing the flow or timing, or pumps water from groundwater and then lets it flow onto the surface, the company needs a permit or water right, even though the quantity of water available in the stream may remain unchanged.

The fact that a company holds a water right does not necessarily mean that there is less water for downstream users. Some water uses do sequester water and make less available downstream. A mine may apply for rights to a water volume that includes both types of uses together—some that decrease the flow available downstream, and some that do not.

So it is not to possible to determine how much water will be available downstream from only the total number in the water rights application, and it is difficult to predict impacts without knowing how much water would be available for downstream uses. Faced with this lack of information, the conservancy's analysts *assumed* that *all* the water in the application would be forever sequestered from the environment and so not available for downstream uses.³⁷

³⁶ Actually, there were nine applications. Three initial applications, one for each drainage, that included all surface and groundwater within the area of the mine and tailings facilities, a second set of three that provided some additional information requested by the state, and then a final set of three applications that identified only the groundwater component included in the previous applications.

³⁷ In fairness, the 2006 water right applications do say that “At this time no return flow or discharge of water is anticipated during construction or operations.” But that sentence is somewhat balanced by a similar sentence, noting that the company was considering “options for compensating for the water appropriated.” (One such option might be, for example, putting water back into the stream). Finally, the applications make clear that not all of the three sources would be used at the same time, something not referenced in the conservancy's assessment. The conservancy analysts could have contacted Pebble staff to find out more about what the 2006 applications mean, but they didn't (and it is unknown whether Pebble staff would have cooperated, if they had).

The author completed three tasks to determine whether that assumption was reasonable:

- 1) Contacted staff at the Pebble project to ask whether all the water in the 2006 applications would be withdrawn from downstream uses.
- 2) Reviewed the 2006 applications to determine if they are consistent with the assumption that all the water would be sequestered.
- 3) Compared the water volumes in Northern Dynasty's 2006 application with water use at the Fort Knox and Red Dog mines.

Contact with Pebble Staff. When contacted by the author, Pebble scientists indicated that approximately one-half to one-third of the total amounts in the 2006 application would likely be unavailable for downstream uses.³⁸

Water Use in the Application. In a mine, the major water uses that sequester water from downstream uses are evaporation, water retained in tailings/waste rock, and water retained in concentrate. With minor exceptions, all other water uses recycle water—that is, some water is required at start-up, but then the water is used again and again without requiring more. Other water is “used up” during the process and requires replacement. Of such uses, the water retained in the tailings voids is by far the largest use.

That's true in Northern Dynasty's 2006 water rights application: the largest water use category is water retained in tailings and waste rock voids. However, the 2006 application also included another surprisingly large category: water in the tailings pond.

At mines with tailings ponds, water on the surface of the pond is recycled for use in the mill. During milling, tailings are discharged into the tailings pond. As the tailings settle out, some water remains on the surface, and some water is permanently sequestered in the tailings voids. The water that remains on the surface is taken back into the mill, and the process repeats. The volume of water in the tailings pond may increase marginally as the pond grows to cover a larger tailings area (or it may not, depending on the geometry of the tailings and other factors). However, it is the loss of water in the tailings void that requires adding fresh make-up water from outside the mine.

The 2006 application includes a large volume for use in the tailings pond itself. The applications forecast 33,700 acre-feet/year for tailings Site A, and 25,000 acre-feet/year for tailings Site G.³⁹ The diagrams in the application indicate the ultimate surface area of the water in the tailings lake at Site A would be approximately 3,000 acres. At that acreage, if 33,700 acre-feet of water were added to the pond each year, after 20 years the water in the tailings pond would be 225 feet

³⁸ Ken Taylor and Mike Smith, PLP, personal communications, various dates. This estimate does not include water for power generation at the site, which may or may not be proposed and was not included in the 2006 application. This potential for on-site power generation only increases the uncertainty about water use.

³⁹ These numbers are taken from Table 2, Water in the TSF supernatant pond, in the 9/21/06 Surface Water Completeness Applications. It assumes from the applications that the Talarik Creek and South Fork water is used for Tailings Site A, and that Talarik Creek and North Fork water is used for Tailings Site G.

deep.⁴⁰ This is an unrealistic result; 20 feet deep would be more typical. Even accounting for evaporation of 1.2 feet/year,⁴¹ or for water lost with the concentrate export, the depth of 225 feet is unrealistic. The calculation for Site G produces a similar depth—230 feet.

These author's estimates—water more than 10 times deeper than usual in a tailings pond—mean that the mine would be very unlikely to sequester the total amount of water requested in the 2006 application. So it is also not likely that, as the assessment assumed, all that water would be unavailable for downstream uses.

Comparison with Fort Knox and Red Dog Mines. Water use in a mine is, in part, proportional to the volume of tailings. A number of other factors also affect a mine's water use. For that reason, it's not possible to directly calculate one mine's water needs by comparing it with use at other mines. But comparing the water use per ton of ore implied in the 2006 Northern Dynasty applications with use at the two other open-pit mines in Alaska may be a partial check on reliability of the volumes cited in the applications. When The Nature Conservancy analysts assumed that all the water in the applications would be used, they implicitly assumed that the project would use between 165 and 210 gallons/ton of ore.⁴² The Fort Knox Project water Resources Management Plan (1994) indicated that Fort Knox would use 90 to 110 gallons/ton, depending on the processing scenario.⁴³ The Red Dog Mine's actual use from 1999-2004 was 101 gallons/ton.⁴⁴ Mines are all different, and there is no standard for water use/ton, but the difference between the conservancy's assumptions about water use at the Pebble site, and use at the two open-pit mines operating in Alaska, gives confidence to the conclusion that not all of the water in the 2006 applications would be unavailable for downstream uses.

Uncertainty. The three methods of checking described above show that assuming (as the conservancy's assessment does) none of the water requested in the 2006 applications would be returned to the stream is likely wrong. There is considerable question as to how much of the water in the 2006 application would be available for downstream uses, and even more uncertainty about whether that application will be representative of the final mine application.

⁴⁰ The applications do not include enough detail even to calculate this number with any confidence. The application indicates that Site G would be designed to include 2 billion tons of tailings (Facilities Description in Support of a Water Rights Application, South Fork Koktuli River application 7/2006, page 3). Footnote 3 under Table 2 of the 9/21/06 Completeness Response indicates a deposition rate of 90 million tons per year, giving a deposition life for the site of 22 years. Thus, 33,700 acre-feet/yr times 20 years divided by 3,000 acres gives approximately 225 depth to the tailings lake. The same citation and calculations (only for the North Fork Koktuli applications) for Site A gives an approximate 230-foot depth.

⁴¹ Hydrometeorology Report June 19, 2006, page 4. Submitted with the 2006 Northern Dynasty Surface Water Rights applications. The report indicates 14 inches of lake evaporation annually at the site.

⁴² Calculation is as follows. For Site A: 90 million tons/year ÷ (Total of South Fork Koktuli + Upper Talarik Creek water use [51 + 29 cfs = 80 cfs]). After required unit adjustments, water use comes to 210 gallons/ton. For Site G: similar calculations except using total of North Fork Koktuli + Upper Talarik Creek (34 + 29 cfs = 63 cfs). After required unit adjustments, water use equals 165 gallons/ton.

⁴³ Fort Knox Project Water Resources Management Plan, prepared by Fairbanks Gold Mining, Inc., March 1994, Figure 3-1 and 3-2. Two scenarios involve 36,000 T/day. The first requires 2750 gallons per minute in make-up water; the second, 2245 gallons per minute. With appropriate unit changes these volumes equal 90 and 110 gallons/ton.

⁴⁴ Water use from Geometrix Memo of 12/14/2006, Summary of Red Dog Water Balance. That memo indicated that between 1999 and 2004, water use averaged 159 Mgal/yr for water entrained in tailings, 31 Mgal/yr for water in the concentrate, and 95 Mgal for evaporation. For a total of 285 Mgal/yr. Production for those years averaged 3.1 million tonnes per year (Paul Glavinovich, NANA; e-mail communication 10/4/11). After appropriate unit conversions, this amount equals 101 gallons/ton.

As part of the mine design, the project must set out a water budget—a document that will answer questions about the volume of water to be withdrawn from creeks or groundwater, how the water will be used, and what volume will be available for downstream uses.

A water budget is one of the most important documents a mine produces. It is influenced by the mining rate, tailings grind, and many other mine-design details. Agencies scrutinize water budgets during the permit process. A budget typically goes through many iterations before the mine developer has confidence in it and before the agencies are willing to accept it. Until a water budget is final, and until the Department of Natural Resources proposes a water right volume, how much water the mine will need is unknown. Therefore, there is a lot of uncertainty about the impacts to downstream fish populations, until the water budget process is complete.

But the conservancy’s assessment concludes, “Based on the details of the 2006 water use permit applications, there is very little uncertainty associated with the analysis of loss and reduction in stream flow in watersheds near the proposed mine.” This conclusion misses the major uncertainty in the analysis: once the analysts made assumptions about the water use requested in the application, and also assumed the applications will be indicative of the final mine applications, then little uncertainty remains in their results. But there is very large uncertainty in their assumptions.

Culvert Impacts

The Nature Conservancy’s risk assessment reports that a road approximately 80 miles long from a Pebble mine site to a potential port site on Cook Inlet would cross 89 drainages, 14 of which are officially designated as supporting salmon. These fourteen streams are the largest the road would cross. The salmon value of the remaining 75 smaller streams is unknown. They may or may not be anadromous salmon habitat. The assessment says that 35 miles of habitat is upstream of the 14 known salmon drainages, and could be stranded by non-functional culverts.⁴⁵

After documenting the resources at risk, the assessment references a wide variety of academic and agency literature to demonstrate the high percentages of culverts that are installed incorrectly or fail after installation. One such study analyzed Alaska Department of Fish and Game information about the Copper River watershed and concluded that 57% of culverts of a 244 sample were not passable to fish and that another 28% might not be passable.⁴⁶ The assessment quotes other studies that indicate up to 83% of culverts evaluated in various locations were inadequate for fish passage.

Based on this evidence, the assessment concludes that “risks to salmon populations from culvert placement during road construction for the mine are reasonably likely over the long term” and that “this would virtually eliminate, or substantially reduce upper portions of these small streams (for example, Chokok Creek, Pile River, Canyon Creek, Eagle Bay Creek, and most unnamed creeks) ”⁴⁷. From the discussion that the vast majority of culverts are improperly placed or maintained, and with no discussion of prevention or mitigation measures, the assessment implies the likelihood that salmon would be cut off from tens of miles of anadromous habitat.

The assessment also examines the uncertainty of these conclusions about habitat loss and concludes, “Although information on culvert types expected for stream crossings is unknown,

⁴⁵ On page 43 and 45, the assessment notes that there are 75 miles of anadromous waters upstream of the culvert locations in the 14 identified salmon streams. On page 108, the assessment lists and explains that there are 35 miles of anadromous waters upstream.

⁴⁶ Copper River Knowledge System (CRKS), 2009.

⁴⁷ P. 46

the uncertainty associated with effects to salmon movement from placements is low. Information from Alaska and other states which showed that culverts have historically resulted in impacts to salmon was used to reduce the uncertainty of impacts predicted from the source.”⁴⁸

Overall, the assessment concludes it is “reasonably certain” that the road would eliminate significant mileage of anadromous salmon resources, and that the uncertainty associated with that prediction is “low.” But there are a number of errors in the assessment’s analysis.

Error 1: Bridges v. Culverts. The conservancy’s assessment effectively establishes that culvert problems are common and can cut off upstream salmon habitat. But it fails to take into account that bridges rather than culverts would likely be used to cross many of the streams and rivers along the road. Bridges have fewer impacts and fewer problems than culverts.

The picture in Figure 5 shows an example of the error in assuming all crossings would use culverts. The assessment includes the Iliamna River in its list of 14 stream crossings that could cut off salmon habitat. At the crossing location shown on the Pebble developer’s public maps, the river is 155 feet wide. There is already a bridge over that river, and it seems clear that any new crossing would also use a bridge.

Figure 5. Proposed Iliamna River Crossing Location: 155 Feet Wide



The Alaska Department of Fish and Game regulates crossings of streams with anadromous or resident fish. The department analyzes each crossing before applying specific requirements, but current department guidelines indicate that stream crossings wider than 20 feet generally use bridges, not culverts.⁴⁹ In some cases, companies use bridges for narrower streams, and less

⁴⁸ P. 131

⁴⁹ Robert MacLean, personal communication. August 2011.

frequently they use culverts for wider streams. Every named stream in the conservancy’s assessment, other than Eagle Creek, is wider than 20 feet: Chokok Creek, Canyon Creek, Knutson Creek, Pile River, Iliamna River, and Newhalen River.⁵⁰ For example, Newhalen River is approximately 400 feet wide, and Knutson Creek is approximately 140 feet wide. These waterways would likely be crossed with bridges, not culverts. Many of the unnamed creeks might also warrant bridges. Therefore, the assessment’s assertion that crossings have the potential to “virtually eliminate” the anadromous habitat in Chokok Creek, Pile River, Canyon Creek, and Eagle Bay Creek, is almost certainly incorrect.

The literature summarized in the assessment—even the Alaska literature—appears to evaluate culverts installed during various times, but mostly years ago. These “legacy” culverts can be expected to have more problems than those installed to modern standards, under current permitting requirements. Today, every culvert in a stream with habitat for resident or anadromous fish requires a permit from the Alaska Department of Fish and Game, consistent with modern standards. Presumably, the department’s permitting standards significantly decrease the incidence of poor installation or culvert failure.

Still, even though a number of streams along a road from the Pebble mine site would require bridge crossings, many small streams would be crossed with culverts. Some of those will inevitably include salmon or resident fish habitat—and it is quite likely that some culverts will be improperly installed or will subsequently fail.

Error 2: Failure to Consider Typical Prevention and Mitigation Strategies and Experience from Other Alaska Mine Roads. It is entirely possible to construct stream crossings that avoid significant effects on streams, even using culverts. That requires both good design and prevention and mitigation strategies, including:

- *Design (Preventing problems).* Design all stream crossings to Alaska Department of Fish and Game standards.
- *Construction (Preventing problems).* Construct stream crossings to standards required in permits.
- *Inspection (Mitigation).* Inspect periodically to ensure that crossings are constructed to standards and to identify post-construction problems. Post-construction problems could include erosion from floods, frost jacking, and plugging by beavers: even well-installed culverts do not work forever without maintenance.
- *Repair (Mitigation).* Fix whatever problems are identified by inspection.

In Alaska, only the first step or two are routinely accomplished. The Department of Fish and Game might issue permits for most stream crossings in Alaska, but it lacks the funds to periodically inspect every culvert. Furthermore, when the department or others identify a problem culvert, a responsible party may no longer exist to fix the problem—or the responsible party may be a government agency that requires an appropriation to do the repairs. The department works with government agencies to get repairs when they can work it into their federal funds request or receive an appropriation. The department does not typically demand an immediate fix, whatever the financial consequences, though it is allowed to do so under the law. The lack of inspection and repair may be one reason why failed culverts remain in place.

⁵⁰ Approximate creek widths are as follows: Chokok Creek: 25 feet; Canyon Creek: 30 feet; Newhalen River: 400 feet; Eagle Bay Creek: 12 to 15 feet; Knutson Creek: 140 feet; Pile River: 135 feet; Iliamna River: 155 feet.

That's the general situation with culvert maintenance. But long, large-mine access roads tend to be different. Alaska has 126 miles of such roads with culverts and bridges:

- Red Dog mine road (DeLong Mountain Transportation System), 52 miles
- Pogo mine road, 49 miles
- Greens Creek mine road, 13 miles
- Fort Knox/True North, 12 miles

Unlike most projects in Alaska, mining projects are frequently inspected by the Alaska departments of Natural Resources, Environmental Conservation, and Fish and Game. In addition, the agency inspections are not subject to government funding whims, because in most cases the agency can charge the mine for the inspection. Thus, unlike on other roads in Alaska, the stream crossings along mine roads are inspected at least annually and sometimes more frequently. Problem crossings can be identified quickly.

Another difference is that mine roads (and culverts) have owners—the mining companies—with money and a legally enforceable responsibility to fix problems. Alaska's large mine operators have historically fixed problem stream crossings when inspections identify problems. Further, the state's authorizations for Alaska's large mines have included a requirement for third-party audits of the agencies and the mines. These audits identify problems at the sites and should have identified culvert issues that have not been adequately addressed.

For example, the Greens Creek Mine 2009 Third-Party Mine Audit inspected random culverts and found no problems (page D-7). The Pogo Mine 2009 Audit included inspection of the major road stream crossings (page 17). The Department of Fish and Game reports that culvert problems have been found in audits and that the companies repaired them in a timely way. Anecdotal evidence from employees of that department and others indicates that culvert problems exist but are not common.⁵¹ The frequency of reported problems is far below the figures cited in the conservancy's assessment—likely because of much greater and continuing oversight by the Department of Fish and Game.

Overall, analyzing only culvert installations without also analyzing likely mitigation and prevention strategies overstates the risk of ecological impacts.⁵²

Comparison with other reports. As another way of analyzing the conservancy's assessment of the risks posed by culverts along mine roads, the author checked to see if other analyses not associated with the Pebble mine controversy reached similar conclusions. Those include the Red Dog Mine Extension EIS (2009), the Pogo Gold Mine Project EIS (2003), and third-party audits for the Pogo and Greens Creek mines. Some of these have the advantage that the roads actually existed at the time of the analysis, and so didn't require scientific speculation about the impacts.

- According to the Red Dog EIS, the 52-mile mine access road “includes nine bridges, three major culvert crossings, and 455 minor culvert crossings (page 3-275).” While many or most of those culverts may cross streams without anadromous fish habitat, it is

⁵¹ Robert MacLean, personal communication, August 2011.

⁵² The conservancy's assessment indirectly acknowledges the problem of omitting prevention and mitigation strategies, noting “This analysis was based on historical data on habitat effects resulting from road crossings in general and does not reflect the proposed mine's specific construction techniques or mitigation efforts. With consideration of the possible effects to fisheries from road and culvert crossings, mine developers may reduce or eliminate potential impacts discussed in this assessment to reasonable levels (p. 43).” This caveat—that the mine could greatly reduce culvert risk — is not carried over to the assessment's conclusions about risk to salmon habitat.

noteworthy that issues associated with failed culverts were not identified as significant in the scoping document, public or agency comments, or the EIS.

- The 2003 Pogo Gold Mine Project EIS evaluated the 49-mile road to that mine. The portion that discusses road crossings concludes, “While construction activities and operation would affect some erosion and sedimentation even under BMPs [best management practices], the overall impacts on fish and aquatic habitat would be low and localized” (page 4-99). No significant effects on fisheries as a result of culvert failure are identified.
- Finally, the author’s review of third-party audits of the Fort Knox, Pogo, and Greens Creek mines found that some specifically addressed potential culvert issues, but none identified failed culverts as an important issue.

Overall, a significant incidence of culvert failure along mine roads does not appear to have been an issue with government agencies, including the Department of Fish and Game.

Uncertainty Analysis. Concerning uncertainty in its analysis of likely culvert problems along a Pebble mine access road, the conservancy’s assessment concludes, “Although information on culvert types expected for stream crossings is unknown, the uncertainty associated with effects to salmon movements from culverts placement is low. Information from Alaska and other states which showed that culverts have historically resulted in impacts to salmon was used to reduce the uncertainty of impacts predicted from this source.”

The statement that uncertainty is low on impacts to salmon habitat from culvert placement avoids the sources of uncertainty.⁵³ Culvert placement is only one part of the system that affects ecological risk. Ecological risk is reduced by systematic and frequent inspection and repair. Uncertainty in the assessment’s conclusion is introduced by (1) not acknowledging that wider rivers would be crossed by bridges, not culverts; (2) not discussing the extent to which modern design requirements reduce the incidence of problems associated with older culverts; and (3) not considering typical inspection and repair regimes (prevention and mitigation strategies) used for other hard-rock mine roads in Alaska. Since we cannot know to what extent these prevention and mitigation strategies would be required if the Pebble mine were developed, there may be a much greater uncertainty in the assessment’s conclusions than it acknowledges.

Overall, the examination of the conservancy’s analysis of culvert failure provides a good example of the errors that can be introduced by omitting prevention and mitigation measures in an ecological risk assessment.

Fugitive Dust

The Nature Conservancy had little site- or project-specific data from the Pebble area with which to predict the potential amount and consequence of fugitive dust from a mine in that area. Instead, the assessment uses studies from the Red Dog mine in northwest Alaska to estimate the distribution of dust, the concentration of metals in the dust, and the amount of metal that would reach local streams from a Pebble mine site. It uses a series of scientific models to predict

⁵³ The assessment is correct in that if large number of culverts were placed, some might fail in construction or over time and could cause at least temporary effects. But the potential for “at least temporary effects” is not the conclusion of the assessment. It clearly implies significant loss of upstream habitat, for a significant length of time.

potential metal concentrations in sediment. Because site-specific data for a potential Pebble mine are not yet available, those models are based on assumptions generated in other studies and mines. Using the predicted metal concentrations in the fugitive dust (based on Red Dog mine data), the assessment predicts metal concentrations in stream sediments (using various assumptions), and metal concentrations in stream water.

Overall, the assessment concludes that even with mitigation measures at the mine, fugitive dust would result in continuous and long-term metal contamination of surface waters near the Pebble project. Specifically, it says, “The models predict that, without treatment measures, dust generated at the mine would result in medal-laden soils, with transport mechanisms resulting in continuous, long-term contamination of local surface waters that support multiple salmon life stages. Although the preceding discussions may present an overly simplistic approach to evaluating impacts from dust generated by the proposed mine, a certainty exists that, even with mitigation measures employed at the mine, copper and other metals will likely be mobilized in runoff or leached into surface and/or groundwater over the 40-70 year life of the mine. The actual amount may be higher or lower than predicted, but the current ambient metal concentrations in surface waters within the watershed indicate that any increase in dissolved metals’ fractions could result in negative effects to the most sensitive salmon life stages.”⁵⁴

A number of errors affect the conservancy’s assessment of the fugitive-dust effects.

Error: Selective Use of Red Dog Information. The Red Dog lead-zinc mine in northwest Alaska is a very high-grade mine. The ore deposit has a grade of 21% zinc and 6 % lead.⁵⁵ The Pebble deposit, by comparison, has a copper grade of 0.42%.⁵⁶ As many in the industry put it: The waste rock at Red Dog has higher grade than the ore at most mines.⁵⁷ In part because that very high grade results in a high concentration of metal in the dust, fugitive dust at Red Dog has been extensively studied.

The conservancy’s assessment makes extensive use of some of this information for the Red Dog mine—for example, to estimate distance for dust deposition and to predict the rate at which metals will concentrate in the soil at a Pebble mine site. But it does *not* make use of any of the studies—such as the fugitive dust risk assessment described in Section 4 of this paper—that have looked at whether this dust has in fact contaminated the fish, benthic environment, or water at and around the Red Dog mine.

This omission seems odd, given the extensive and recent publications on the subject, and the fact that Red Dog has much higher metals concentrations in the dust than would occur at a Pebble site. Those higher concentrations would make it much easier to detect dust-induced changes in water quality at Red Dog—but the studies cited below don’t report such changes.

- *Red Dog Mine Road Fugitive Dust Risk Assessment.* Section 4 of this paper described the 2007 DMTS Fugitive Dust Risk Assessment. That study did not conclude that fugitive dust had contaminated water quality near the road or mine.⁵⁸

⁵⁴ P. 84

⁵⁵ Red Dog Mine Closure and Reclamation Plan; Supporting Document B, Plan of Operations; 2009, p. 1

⁵⁶ Pebble Partnership Press Release, February 1, 2010.

⁵⁷ For example, the waste rock at Red Dog has a lead concentration of 1.2% (Teck Comico, 2005. Summary of Mine Related Fugitive Dust Studies, p.3). The *ore* at Pebble has a concentration of 0.42% copper (ibid).

⁵⁸ The study focused on the road; two decades of travel by uncovered ore trucks had caused a local deposition of high concentrations of metals along the roadway. (The trucks are now covered). The Red Dog concentrate has a metals concentration hundreds of times greater than the dust concentration at a Pebble mine is likely to be—so the

- *Red Dog EIS.* The Red Dog Supplemental EIS (2009) discusses fugitive dust but primarily with respect to its effects along the Red Dog road. This extensively reviewed document did not identify fugitive dust's effects on water quality, other than from the road, as an issue for analysis—even though the concentration of metal in the dust around that mine is many times greater than what the conservancy's assessment predicts for a Pebble mine site. The EIS does include water-quality evaluations of streams, including those around the mine site—but they do not show exceedances of lead or zinc, as would be expected using the conservancy's predictive models.

Errors in Red Dog Assumptions. The conservancy's analysts corrected for the difference in metal concentrations at the Red Dog and Pebble sites by using the ratio of concentration of metals in the ore. They used the lead concentration, which they cited as ~4.8% (elsewhere cited as close to 6%)⁵⁹ to Pebble's copper concentration of ~0.6%. That ratio is 8, so the analysts adjusted the Red Dog values for the Pebble site by multiplying by 1/8 (0.125). However, under that logic, they could just have easily made the adjustment using the Red Dog's zinc concentration of roughly 21%, rather than the lead concentration. Using the zinc concentration, the analysts would have multiplied Red Dog values by 0.03% instead of 0.125%. That reduction would have changed the assessment's conclusions about potential contamination by dust.

Also, the conservancy's analysts used the difference in wind speed at the two sites—the average wind speed at Pebble is 60% that at Red Dog—to correct the distance the dust would travel, but not the amount of dust that the wind would collect. The different wind speed could affect both.

The largest potential error in the assessment is not accounting for differences in dust sources at Red Dog and Pebble sites. The table shows potential dust sources and metal concentrations at Red Dog.⁶⁰

Red Dog Mine 2003 Average Grade		
	Lead	Zinc
Ore	5.6%	20.7%
Waste	1.2%	1.2%
Tailings	1.7%	3.8%
Lead Concentrate	54.5%	13.0%
Zinc Concentrate	3.2%	55.5%

metals concentration in the area of deposition will be hundreds of times higher than at any locations likely to be affected by dust from a Pebble mine. On the other hand, the deposition from Red Dog is concentrated in a smaller area—near the road rather than throughout the watershed. But the question of dust-carried metal concentrations much higher than would likely occur in Pebble or other Alaska mines is relevant to the discussion.

⁵⁹ The difference between the conservancy's citation that indicates a lead concentration of 4.8%, and the citation in this report that indicates almost 6% does not indicate any significant problem. The two citations may reflect the condition of the ore body at different dates, or include different level of reserves, etc.

⁶⁰ Summary of Mine Related Dust Studies. Red Dog Mine Site. Teck Cominco, March 14, 2005. Table 1, p. 3.

Figure 6 shows an aerial photograph of the Red Dog Mine in 2003. The labeled areas show the approximate locations of the major mine features: the pit, the waste rock, and the exposed tailings. The mine facilities are visible but not circled. There are a number of important dust sources at Red Dog that might not contribute to dust or metal concentrations at a Pebble mine site. Specifically, waste rock is a major dust source at Red Dog; it is large, prominent, and elevated above the surrounding landscape, and it has a significant concentration of metals (1.2% of lead and zinc). It is likely a significant source of dust and dust with metal concentrations. At Pebble, the 2006 applications indicate that the potentially acid-generating waste rock would be placed under water, eliminating the dust potential.⁶¹

Figure 6. Red Dog Mine 2003



Also, a very large source of contaminated dust is the concentrate itself. That source has received the most attention at Red Dog. The concentrate source of fugitive dust was the uncovered haul trucks (now covered), and incidental dusting of the haul trucks during loading (Red Dog now uses an indoor truck wash to minimize this source). While concentrate dust may not be a large component of the overall fugitive dust volume, it is a significant source of the metals in the dust, because it is approximately 50 times more concentrated than in the waste or tailings. The problem of fugitive dust from concentrate is unlikely to be relevant at Pebble. The conservancy's assessment discusses a concentrate pipeline, which would not create fugitive.

The Red Dog studies have not quantified the contribution of each fugitive dust source. Nevertheless, the waste rock stockpile and the concentrate are likely to be a large portion of the quantity of dust and of the metal content in the fugitive dust. Neither is likely to be relevant at a Pebble mine site. Therefore, the predictions in the conservancy's assessment, which implicitly

⁶¹ It is likely that the potentially acid-generating waste rock is also the waste rock that has metal content. The tertiary sediment that comprises the non-potentially acid-generating waste rock that the 2006 application indicates would not be placed under water is not likely to have significant metal content—though without more information, that conclusion can't be confirmed.

include these sources, would be a significant over-estimate of the dust amount and metals concentration at a Pebble mine.

Error: Failure to Include Prevention/Mitigation Measures in Place at Red Dog. The conservancy's assessment predicts copper content in fugitive dust from a Pebble site based on the growth in metal concentrations at Red Dog from 1989 to 2004. It takes the metal concentrations in the soil for those two dates and does a straight-line interpolation to determine the annual growth in metal concentration. However, a dust study at Red Dog notes that between those two dates, "Improvements have been made that have eliminated or greatly reduced some particulate sources."⁶² In fact, between 1991 and 2004, the Red Dog operator implemented 23 improvements—some extensive—to decrease the amount of fugitive dust from the mine.⁶³

Presumably, those improvements did reduce the dust, and therefore the annual amount of fugitive dust from the mine would have decreased significantly between 1989 and 2004. So a straight-line interpolation to determine the annual growth would significantly over-estimate the current rate of growth metal concentrations in soil at Red Dog. If the annual growth is over-estimated for Red Dog, it would also be over-estimated for the Pebble site, since that is based on the Red Dog information. This conclusion assumes that at least some of the prevention and mitigation measures in place at Red Dog would also be implemented at a Pebble mine.

Error: Failures to Include Prevention/Mitigation Measures or Site-Specific Characteristics at Pebble. Many measures can be implemented at a mine to decrease the amount of fugitive dust. As indicated above, Red Dog implemented 23 measures to control dust over 13 years. The conservancy's assessment indicates this omission, noting "the analysis does not consider possible dust control best management practices (BMP) such as those that have recently occurred at Red Dog Mine."⁶⁴ Taking into account significant measures to control dust would change the assessment's conclusion about the effects of fugitive dust at a Pebble mine site.

Dam Failure

Northern Dynasty's 2006 water rights applications were accompanied by applications for tailings dams that would hold large volumes: two billion tons of tailings at Site A and 450 million tons at Site G. The proposed dams themselves would be extremely large; the largest proposed dam at Site A was 740 feet and the largest at Site G 450 feet. Obviously, if such large dams failed, the consequences could be extremely severe, depending on the type and extent of failure.

The Nature Conservancy's assessment included a long list of failures at tailings dams around the world. An appendix cites 88 such failures between 1961 and 2009 and references an even larger number—147 failures worldwide—but doesn't specify a time period. The assessment describes many examples of such failures and their consequences. Some of the dams should never have been built—and some never would have been built in the U.S. But some of the failures did occur in developed places, including the U.S., Scandinavia, and Western Europe.

⁶² Summary of Mine Related Dust Studies, Red Dog Mine. Teck Cominco Alaska. March 14, 2005, p.2.

⁶³ *ibid*, Appendix II. One of the 23 improvements was later abandoned.

⁶⁴ P. 67

The conservancy's assessment does not predict the likelihood of a dam failure at a Pebble mine site. It may not be possible to predict the likelihood of such a low-probability event: despite the documented tailings dam failures, such failures are not common.

But it would have been helpful if the assessment had included a discussion of the different construction methods and techniques (prevention/mitigation) that minimize the likelihood of failure, and that result in stronger and more stable tailings dams. From the literature review in the assessment, it would appear that the literature is unable to quantify the extent to which certain techniques decrease the incidence or consequence of dam failures. But author's conversations with experts make it clear that some construction methods are safer than others: downstream versus upstream construction; rock core versus unsorted gravity dams; foundations that extend to bedrock versus those that do not, and others. Without that discussion, the assessment leaves readers with the incorrect impression that dam failure is solely a statistical event—that dams sometimes just fail, and there are limited ways to prevent failures or prepare for them.

After the discussion of dam failures, the assessment mostly describes the environmental effects of a catastrophic failure. In general it concludes that “A failure of one of the tailings dams planned for the proposed mine would have both short and long term impacts on receiving waters, with severity depending on dam release volume, timing, and location.”⁶⁵ This author agrees with that conclusion. But while the general conclusion is accurate, some of the more specific predictions of impact in the body of the report are predicated on questionable assumptions.

Error: Chemical Assumptions. The assessment assumes that the water in the tailings pond would be acidic, with dissolved copper and other metals in solution. There is no analysis to justify this assumption; it is just asserted. In fact, as reported earlier, Northern Dynasty's 2006 water rights and dam safety applications indicated that the tailings would be separated into potentially acid-generating tailings (3%) and the much greater volume of non-potentially acid-generating tailings (97%). The technique proposed in the applications would be placing the potentially acid-generating tailings lower in the tailings stack; in that situation, the overlying water in the tailings pond would have no contact with potentially acid-generating tailings. While there is not enough data or design information to evaluate Northern Dynasty's assertion that it could separate the potentially acid-generating tailings, the conservancy's assessment simply ignores it. Instead it makes the unsupported assertion that the water on top of the tailings would be acidic, with the associated high levels of dissolved metals. Data required for permitting will specifically address the question of acidity and water quality in the tailings lake—but it is not possible to predict tailings water quality with the limited project-specific data in the 2006 applications.⁶⁶

Other Information and Run-Out Distances. The conservancy's assessment uses an empirical relationship from a journal article to assert there is a good chance that a significant tailings dam break would result in tailings reaching down the Koktuli River to Bristol Bay itself. The assessment includes some but not all of the caveats from the journal's authors and tends to convey an overly optimistic view of the reliability of its conclusions.

⁶⁵ p. 90

⁶⁶ The author's familiarity with tailings water in Alaska indicates that such water may not meet water quality standards. But that does not mean that the waters will be acidic or have the high concentration of metals that the conservancy's assessment assumes, or that the water would be toxic to aquatic life.

The journal article uses regression equations from a data set of 28 mostly tailings dam failures to statistically predict downstream run-out, based on dam height and the volume of tailings released in the failure.⁶⁷ While regression equations based on general characteristics of a dam provide an interesting first approach for assessing downstream vulnerabilities, they are not a substitute for detailed analysis based on project- and site-specific data. The assessment quotes from the article:

The diversity of the tailings dam characteristics (dam type, dam situation, dam foundation, storage volume, etc.) make any universal prediction assessing failure impacts very speculative. In addition, detailed risk assessments involve timely and costly geotechnical, hydrologic and hydraulic studies which can only be completed with the complicity of either or both the mining companies and political authorities.⁶⁸

The article goes on to say, “It is evident that the results need to be treated with caution, due to the uncertainty present in documentary evidence and the diversity of the tailings dams.”⁶⁹

In addition to the “speculative” and “first assessment” nature of predictions using the journal’s methodologies, the conservancy’s assessment uses the equations far beyond the range of the data set. The 28 failed dams used in the analysis had an average height of 79 feet and a standard deviation of approximately 46 feet; the dams ranged from 16 feet to 216 feet high. The dams proposed in Northern Dynasty’s 2006 water rights applications would be much higher. Site A includes dams up to 740 feet high, and the largest dam at Site G was proposed to be 450 feet high.

While it is logical to expect that downstream run-out distance would increase with dam height, the specific relationship might not be valid. The height proposed for a dam at Site A is 14 standard deviations away from the data-set mean height. It is almost 3½ times the maximum height of the tallest dam in the data set, and more than 5 times the height of the second tallest dam. The small data set and the large extrapolation beyond it provide some reason to question the validity of the empirical relationship of those values.

There is also theoretical reason to question the application of the equations to dams of this height. The equation requires an estimate of the proportion of tailings that would escape during a dam failure. But tailings dams are different from water retention dams. Unlike water, compacted tailings have some structural value. As the journal article notes, “In most failures, tailings ponds are never emptied and, indeed, only a limited portion of the mine waste is released.”⁷⁰ Different types of dam failures may release tailings differently. However, for many types of failures, the water stored with the tailings is important to mobilizing the tailings into and increasing a breach from a failing dam. The greater the volume of mobile water relative to tailings behind the dam, the greater the volume of tailings that will likely escape in the event of failure.

⁶⁷ The relevant equation from the article is: $D_{\max} = 1.61 \times (HV_F)^{0.66}$ $r^2 = 0.57$. The maximum runout distance (D_{\max}) in Km is equal to 1.61 times the product of dam height (H in meters) and the volume of tailings that released (V_F in million cubic meters) raised to the power of 0.66. Rico et al, p. 82.

⁶⁸ Rico et al., p. 85

⁶⁹ Ibid, p. 86

⁷⁰ Ibid, pp. 80-81.

In the data set used to estimate the equation the conservancy assessment uses, the proportion of stored tailings released in a failure varied from 2% to 80%, with an average of 35%. But the proportion of mobile water content in the tailings, and the ability to mobilize tailings during a dam breach, would likely decrease as dam height increases. That is, as the tailings compact under the weight of hundreds of feet of tailings, the lower elevation tailings store much less free water than those at the top of the pile. That difference could easily affect the relationship in the equation, especially as applied to a dam height 14 standard deviations beyond that of the data set.⁷¹

Some construction and management regimes are likely to minimize the mobile water in the tailings. Some designs store great amounts of mobile water. These prevention and mitigation techniques cannot be included in a “preliminary” or “speculative” series of equations. They can be considered in a site-specific analysis of data and designs that would be available during a permitting phase for any Pebble mine.

This uncertainty is compounded because the conservancy’s assessment considers only failures that release a proportion of tailings near the average or greater, but not less. In the data set used by the journal authors, the dam failures released an average of 35% of the stored tailings. So analysts might be expected to choose the mean, and some reasonable deviations around the mean. The assessment did not do that, but instead chose 25%, 50%, 75%, and 100% tailings release. Since only one of the data points in the journal article was significantly more than 50%, the assessment’s choice of data likely conveys an overestimate of the scale of catastrophe in the event of dam breach at the Pebble site.

Without a site-specific, detailed analysis of the features of the proposed dams (which are unknown at present), the extent of downstream impacts can’t be reliably predicted. The journal article acknowledges that, as does the body of the conservancy’s assessment. But the assessment fails to acknowledge the level of uncertainty in its conclusions.⁷²

⁷¹ The journal article did investigate whether the volume of tailings released in a dam failure was related to dam height. It found that the best predictor to use was the average—that the proportion released did not decrease with dam height. However, that lack of relationship may be due to the small data set, and the variability in dam failure type and dam designs, as well as the fact that the data did not give the authors the ability to control for volume of mobile water. For some type of designs and failure mode, it is likely that the volume of mobile water does affect tailings mobility in the event of a breach.

⁷² While the conservancy’s assessment acknowledges these limits, it justifies ignoring them because of the large size of the proposed Pebble dams, and by what appears to be an inappropriate comparison with the Los Frailes dam failure in Spain, which was caused by foundation failure. That specific failure mechanism may have influenced the proportion of tailings that spilled and the run-out distance. Foundation failure is one of the least likely causes of dam failure when engineered facilities are keyed into bedrock. For that reason, it may not be an apt comparison.

Summary: Why Assessment Conclusions Not Supportable

The Nature Conservancy's ecological risk assessment comes to scientifically unsupportable conclusions about the risks of mining to Bristol Bay salmon. It does so because the lack of data meant the analysts had to make assumptions that don't necessarily reflect what a mine at the Pebble site would look like; the developers haven't yet submitted a design. That problem is compounded because the analysis also omits prevention and mitigation strategies that the mine developers might propose or the government will require; again, such strategies can't be known, in the absence of a mine design. The next two pages summarize how the lack of project- and site-specific data affects the results of the assessment.

Use of an Unrealistic Base Case

For each of the subjects we just discussed, the conservancy's analysts lacked the information to construct a realistic base case, and therefore made unjustifiable assumptions.

- ***Acid Rock Drainage.*** The analysts lacked project- and site-specific information they needed to understand whether the tailings would be acid-generating, and whether any acid-drainage that formed would escape from the mine's containment system. Instead, they assumed that acid-mine drainage would form and escape the mine site in a volume and acidity characteristic of abandoned mines from decades and centuries ago. There is no justification for this assumption.
- ***Water Withdrawal.*** The analysts lacked information to assess how much of the water Northern Dynasty applied for in its 2006 water rights applications would be unavailable for downstream uses. Therefore, they assumed none of it would be available and predicted risk to salmon habitat on that basis. That assumption isn't justifiable; until a water budget is final, and until the Department of Natural Resources proposes a water right volume, how much water a mine will need is unknown.
- ***Culvert Failure.*** The analysts did not know which streams along a road from the proposed mine would be crossed with bridges and which with culverts. The discussion in the assessment did acknowledge the potential for using bridges at some crossings, but all the tables and conclusions in the assessment assumed that all waterways would be crossed with culverts. In fact, the Alaska Department of Fish and Game's guidelines for the bridge/culvert decision indicate that crossings wider than 20 feet typically require bridges; major crossings that are named in the assessment would therefore almost certainly use bridges, which have fewer impacts and fewer problems than culverts.
- ***Fugitive Dust.*** The analysts drew conclusions about the risk from fugitive dust at the Pebble mine site using Red Dog mine data, and concluded fugitive dust would contaminate surface waters near the Pebble project. This paper documents errors they made in their analysis, the most important being that they did not review available data on whether fugitive dust from Red Dog mine has affected water quality in nearby streams and lakes. Since the concentration of metals in dust from Red Dog is higher than it is likely to be in dust from the Pebble deposit, Red Dog dust would be more likely to create water quality problems—but as discussed earlier, studies to date haven't found evidence of dust-induced changes in water quality as a result of dust from Red Dog.
- ***Dam Failure.*** The analysts did not try to predict the likelihood of dam failure at a Pebble mine site. But should a dam fail, they predicted a catastrophic base case using regression equations of questionable applicability.

Omitting Prevention and Mitigation Strategies

For each of the five subjects discussed earlier, the analysts assessed the ecological risks without including prevention and mitigation strategies that could reduce those risks. In most cases, they couldn't do so: at the pre-design stage specific prevention and mitigation strategies are unknown. The developer has not yet proposed them, and government agencies have not considered what they will require. The problem with the omissions are summarized below.

- **Acid Rock Drainage.** The analysts did not consider the prevention strategy Northern Dynasty referred to in its 2006 applications—separating the potentially acid-generating from the non-acid generating the tailings, and sequestering the potentially acid-generating tailings from oxygen and the environment. Nor did they consider the possibility of any other method to prevent contamination, of monitoring by the government or company, or of a back-up containment in the case those methods didn't work. But there is no site-specific data to assess whether such measures would work to protect salmon or not, and no data to assess whether and how much they would decrease the ecological risk.
- **Water Withdrawal.** Northern Dynasty's 2006 applications made a vague reference to strategies that might mitigate the effects of withdrawing water from the ecosystem, but there was not enough information to include any such strategy in the conservancy's assessment.
- **Culvert Failure.** There are standard prevention and mitigation strategies used to prevent culvert failure and limit the consequences when they do fail: design standards, construction to design, inspection, and repair. The conservancy's assessment omitted any discussion of these measures, even though they are known, and even though Alaska has 129 miles of mine roads from large mines with which to assess whether they work. Consideration of the results of the 129 miles of existing roads shows that the conclusions of the conservancy's assessment are significantly overstated. Because culverts have standard prevention and mitigation strategies, this section shows the consequences of omitting such strategies on the assessment of ecological risk
- **Fugitive Dust.** The assessment's predictions about the effects of fugitive dust were based on data from the Red Dog mine, but it did not include any discussion about the improvements the Red Dog operator has made to reduce fugitive dust—or how such measures might help at a Pebble mine.
- **Dam Failure.** Not all dams are alike. Some construction techniques result in stronger and more stable dams; some may limit tailings escape even in some breach modes. The pre-design assessment wasn't able to evaluate such potential prevention and mitigation techniques, because the Pebble developer has not yet submitted designs for dams.

A pre-design ecological risk assessment might have been able to discuss more potential prevention and mitigation strategies for a Pebble mine, if such strategies were not so site-specific. But hard-rock mines are all different from one another. Challenges posed by the geochemical make-up of the ore, and by the environment, are different in different locations. These differences can occur in locations close to one another. And different mines come up with different solutions to the issues each location presents. Omitting these strategies results in an analysis that likely exaggerates the risk to salmon. In fact, agencies could not legally permit some of the risks portrayed in the conservancy's assessment.

Section 6. Conclusion

Scientifically sound ecological risk assessments require a great deal of data. The assessments of the Kensington mine's proposed disposal of tailings, and the effects of fugitive dust along the Red Dog mine road, are extremely detailed, as discussed in Section 4. These post-design assessments used information from testing specific project parameters (bench-scale testing of Kensington tailings) or of actual sampling (metal concentrations along the Red Dog Road). Analysts used data (bathymetry of Lower Slate Lake) only available when the specific mine site was known. They gathered data (metals bioaccumulation in benthic organisms on Kensington tailings; sampling plant tissue along the Red Dog Road) specific to the projects. Having these project-specific details and knowing the environmental characteristics of the specific sites allowed analysts to draw scientifically supportable conclusions in these assessments.

By contrast, the pre-design assessment methodology The Nature Conservancy used to evaluate the ecological risks of large-scale mining to Bristol Bay salmon is based, in the absence of site- and project-specific data, on various assumptions about what would happen. This paper has shown that many assumptions were unjustified and resulted in unsupportable conclusions that most likely exaggerated the ecological risks.

Every hard-rock mine in Alaska is unique. They each use different methods to protect water quality and fish populations. The geochemical characteristics of ore and tailings also differ for every mine in Alaska. Some mines have different ore characteristics within the same ore body, or within nearby ore bodies. Milling processes are engineered for individual mines.

And each mine site is different. In fact, even the two tailings sites proposed in Northern Dynasty's 2006 applications—and reviewed in the conservancy's assessment—differ significantly. Site G is a mountain valley with little groundwater flow, and Site A is within an open valley with significant groundwater volume. From the applications, it appears that the developer expected about one-quarter of the water captured at Site A to be groundwater, while at Site G groundwater was expected to be only 1/340 of the volume. This is a very significant difference. The Pebble developers have said they are no longer considering the conceptual mine design submitted in 2006—so the tailings site ultimately proposed for a mine could be significantly different from either of these. Such differences influence the ecological risk.

The variability among mines is why mine permitting is such a data-intensive process. Without data from individual mine design and site configurations, government agencies cannot determine whether mines meet permitting standards. It takes a large amount of environmental baseline and mine design information for the agencies to evaluate whether to issue permits for hard-rock mines, and it takes a large amount of data for agencies to prepare an EIS to illustrate the environmental consequences of a proposal. Those processes are very much like those used in an assessment of ecological risk. In fact, formal ecological risk assessments are often part of the permitting/EIS process. It is unlikely that a pre-design ecological risk assessment could provide as quantifiable answers as an EIS with much less data.

This comparison of post- and pre-design risk assessment in this report shows that the detailed information, about a specific site and a specific mine design, and without specific knowing the specific prevention and mitigation strategies that will be applied, it is not possible to use ecological risk assessment methodology to evaluate the risks a proposed mine might pose to the environment. Specifically, a pre-design ecological risk assessment is a failed methodology for evaluating ecological risks from hard-rock mines in Alaska.

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